DOCUMENT RESUME

ED 070 577 SE 014 124

TITLE	Fundamentals of Petroleum.
INSTITUTION	Bureau of Naval Personnel, Washington, D. C.
REPORT NO	NAVPERS-10883-A
PUB DATE	65
NOTE	209p.; Revised 1965
EDRS PRICE	MF-$0.65 HC-$9.87
DESCRIPTORS	Chemistry; *Fuels; Geology; Instructional Materials; *Military Science; *Military Training; Petroleum Industry; *Post Secondary Education; Safety Education; *Supplementary Textbooks

ABSTRACT

Basic information on petroleum is presented in this book prepared for naval logistics officers. Petroleum in national defense is discussed in connection with consumption statistics, productive capacity, world's resources, and steps in logistics. Chemical and geological analyses are made in efforts to familiarize methods of refining, measuring, sampling, and testing petroleum products. Military specifications are described with a background of property requirements of kerosene, lubricating oils and greases, aviation and automotive gasolines, and jet, diesel, and burner fuels. In quality surveillance, deterioration, contamination, and reclamation aspects are presented in relation to bulk storage facilities; and in safety precautions, hazards, fire, and explosion are mentioned in relation to pipelines, tank cars, tank barges, tank trucks, and, especially tanker operations. Also included are operational procedures at fuel depots. Illustrations for explanation purposes, a glossary of general terms, and a reference list of publications are included. (CC)

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FUNDAMENTALS OF PETROLEUM

Prepared by

BUREAU OF NAVAL PERSONNEL

NAVPERS 10883-A

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PREFACE

During World War II, petroleum furnished the fuels, lubricants, and many other essential products needed for the large quantities of mechanized equipment utilized by the Armed Forces in carrying out the war effort. It is assumed that petroleum will continue to perform the same functions in any conflict in the foreseeable future.

The role of the petroleum logistics officer in getting petroleum supplies to the military forces at the right time and place, and in the proper amounts, is frequently emphasized. However, the matter of ensuring the essential qualities of these products on arrival at destination, though of equal importance, is too often overlooked by those unaware of probable consequences. Therefore, Fundamentals of Petroleum has been prepared to provide petroleum logistics officers with sufficient technical background to enable them to understand some of the problems they will encounter in handling this product.

Although designed specifically for petroleum logistics officers, Fundamentals of Petroleum should also be useful to the technical officers having highly specialized knowledge in only one aspect of petroleum; to officers in various billets—such as MSTS and Service Force billets—where some knowledge of petroleum is highly desirable; to Line officers of the Regular Navy; and to officers of the Naval Reserve who wish to further their professional training. This book will also serve as a review for personnel who at the present time are intimately concerned with petroleum. Although prepared specifically for naval officers, Fundamentals of Petroleum should be helpful to officers of the Army and of the Air Force because petroleum is handled jointly in all major areas.

Whereas this book provides general background information for personnel concerned with petroleum either directly or indirectly, it is not intended as a comprehensive text for the training of petroleum experts. (The training of petroleum experts qualified for technical billets requires long periods of formal schooling and extensive experience.) Moreover, Fundamentals of Petroleum does not supplement nor supersede the official operational manuals promulgated by cognizant authorities.

Fundamentals of Petroleum was originally prepared by the U. S. Navy Training Publications Center for the Bureau of Naval Personnel in 1953. It has been revised for the Bureau of Naval Personnel as a joint project of the Education and Training Support Services and the Navy Fuel Supply Office. The revised publication contains some material from Petroleum Logistics, NavPers 10892, which is obsolete and will no longer be published. In addition, the Defense Fuel Supply Center provided assistance in the preparation of chapter 2, "Petroleum Resources", and MSTS in the preparation of chapter 12, "Transportation of Petroleum Products", and chapter 13 "Tanker Operations".

Special gratitude is expressed for the help of the American Petroleum Institute which has provided valuable advice and assistance, and has most generously supplied information and permission to use copyrighted materials as noted elsewhere.

Original edition 1953

Revised 1965

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CHAPTER 1

PETROLEUM IN NATIONAL DEFENSE

On 19 January 1948, James Forrestal, then Secretary of Defense, made the following statement before the Special Subcommittee on Petroleum of the Armed Services Committee of the House of Representatives:

"There was a time when the major item of supply to a fighting force was food, as Napoleon graphically pointed out when he said that an army marches on its stomach. In World War II, however, the volume of liquid fuel shipped overseas was nearly 16 times that of food. Petroleum and petroleum products amounted to over 60 percent of the overseas military shipments."

It is estimated that in the later months of 1951, petroleum comprised as much as 62 percent of the total tonnage required for the support of the United Nations forces in Korea.

The tremendous emphasis on petroleum shipments indicates the importance of petroleum as a war material. A modern Navy, Army, Air Force, or Merchant Marine is largely dependent in its operation on the oil-burning engine, whether it be steam or internal combustion. Vast quantities of special petroleum products are required, not only for fuel, but for lubricating engines and other equipment. In addition, modern warfare requires many other petroleum products. For example, ordnance equipment must have oil for hydraulic recoil equipment and power drives; petroleum jellies are required for fire bombs, and gasoline for flame throwers; petroleum greases, oils, and waxes for protecting equipment; kerosine[1] for lighting and heating; and petroleum compounds for sanitation and medicine.

Petroleum, besides providing those products usually associated with its name, produces the bulk of the supply of toluene (basic component of TNT) and, furthermore, is one of the principal sources of butadiene and other components of synthetic rubber. Both toluene and synthetic rubber were critical items during World War II, and may reasonably be expected to have the same importance in any war in the forseeable future.

PETROLEUM AND STRATEGY

Because petroleum is an indispensable component of modern warfare, strategies are fashioned accordingly. Military experts are of the opinion that in World War II the Germans entered Roumania and southeastern Europe to obtain the oil required for their war machine, and may have attacked Russia to get more oil. Japan, short of oil supplies, directed her initial attacks to obtain, among other vital commodities, the rich oil fields of the East Indies. Allied strategy sought to deprive both adversaries of petroleum supplies as quickly as possible. Fuel depots and refineries were primary bomber targets; tankers were targets of choice for our submarines. Likewise, the German submarines concentrated on our tankers in the battle of the Atlantic, creating a precarious situation in the early days of World War II.

Important as oil is to the military forces of our country, it is no less important to our civilian economy. One of the critical problems in emergency is to calculate the balance between military requirements and essential civilian needs, as it is clear that the continued prosecution of a long war depends, in the last analysis, on a sound civilian economy. Modern warfare is not only military mobilization; it is total mobilization. Accordingly, petroleum's

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[1] Throughout this book, kerosine is spelled with an i in accordance with the preference of technical societies in order to indicate its source, which, like that of gasoline, is the light distillates from crude petroleum.

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part in military logistics will be seen in better perspective after a discussion of the place of petroleum in our national economy.

TRENDS IN U. S. CONSUMPTION

Since the first oil well was drilled in 1859, petroleum has become increasingly important—first as a source of light, later as a source of power and heat. Figure 1-1 shows the trend in the use of petroleum as a source of energy in the United States from 1900 to 1960.

It will be noted that at the outset of World War I, oil was relatively unimportant. However, the construction of oil-burning ships brought about a rapid change in this picture. At the beginning of the war, the U.S. Navy had only two battleships using fuel oil exclusively, but in 1918 alone, in its emergency shipbuilding program, 811 oil-burning ships, including submarine chasers, submarines, destroyers, and larger types were constructed.

By 1932, Navy ships were 100 percent oil-burning. The consequent growth in fuel oil consumption is shown in table 1-1. As indicated in table 1-1, no distinction was made between heavy fuel oil and the lighter grades suitable for use in diesel engines until 1924.

Prior to World War II, submarines were the major type of Navy craft using diesel oil as a fuel. During and subsequent to that war, however, the types of Navy vessels utilizing diesel fuel have been extended to include destroyer escorts, ammunition ships, cargo ships, mine-sweepers, gasoline tankers, coastal transports, salvage vessels, tugs, patrol craft, and landing craft of all types.

Commencing in 1955, the U.S. Navy added a number of nuclear-powered submarines and a few large nuclear-powered ships to the Fleet.

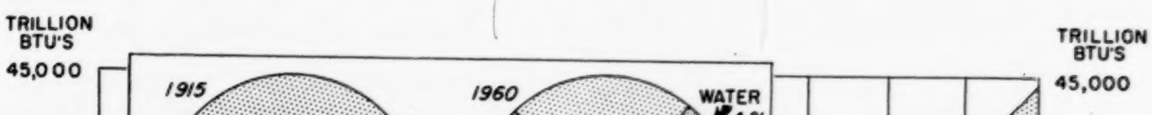

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Figure 1-1.—U.S. energy sources from 1900 to 1960.

It can be anticipated that additional nuclear-powered vessels will be added to the Fleet in the future; however, it is expected that oil-burning ships will comprise the major portion of the Fleet for many years to come.

About 96 percent of the world's merchant fleet was coalburning prior to World War I. However, that war gave impetus to the construction of oil-burning merchant ships because they were found to have maximum cargo space, quick turn-around, and greater speed. This trend, set by the merchant shipbuilding program of World War I, continued until, by 1948, three fourths of the world's merchant ships depended upon oil.

Table 1-1.—Navy Fuel Oil Consumption, Ashore and Afloat, 1916-1964

Year	Fuel Oil (Bls. of 42 U.S. gals.)	
1916. . .	1,100,000	Includes diesel oil
1920. . .	5,800,000	
1925. . .	7,000,000	
1930. . .	6,300,000	
1935. . .	8,000,000	
1940. . .	11,000,000	
1945. . .	154,800,000	
1950. . .	23,000,000	
1955. . .	37,000,000	
1960. . .	32,100,000	
1964. . .	37,000,000	

Consumption of petroleum products increased rapidly after World War I as the country became more and more merchanized. Between 1918 and 1940, the number of automobiles in use in the United States increased from about 5 1/2 million to about 27 1/2 million. Similarly, the number of planes, motor trucks, tractors, buses, and equipment such as bulldozers and cranes increased. Oil-burning equipment was installed on railroads and in manufacturing plants, farms, and homes. The U.S. domestic demand for all liquid petroleum products between 1920 and 1960 is shown in figure 1-2.

A comparison of the relative volumes of major petroleum products consumed in the United States from 1900 through 1949 shown in figure 1-3 reveals the fact that, by 1930, gasoline had become the major petroleum product.

The period from 1929 to 1960 has shown an upward trend in the demand for all petroleum products. There was little change in the relative amount of increase, even during the period 1941-1947.

U. S. PRODUCTIVE CAPACITY

The detailed analysis of the ability of the United States to meet increasing petroleum demands or to substitute other sources of energy for petroleum is beyond the scope of this book. However, a brief consideration of these factors is pertinent.

The need for maintaining petroleum reserves in the interest of national security has been widely recognized in both State and Federal governments. In many cases, States have enacted oil conservation laws to prevent the waste of reserves by careless drilling and exploitation. The Federal Government has established naval petroleum reserves in California and in Alaska, in addition, the Navy has oil shale reserves in Colorado and Utah. At present the production of oil from shale cannot compete commercially with production from petroleum. Similarly, synthetic liquid fuels prepared from coal and other sources are not being produced commercially because of the cost, although constant research is being carried on in this field. The Navy is using nuclear energy to propel submarines and certain few surface ships; however, it is doubtful that nuclear energy will replace petroleum in the immediate future. Only in very specialized and isolated instances has nuclear energy been able to compete economically with petroleum. An example is in the Antarctic, where a nuclear power plant can be operated more readily than a conventional power plant using petroleum because of the difficulty of resupply of petroleum fuels. Therefore, natural petroleum remains vital to our economy and to our national security.

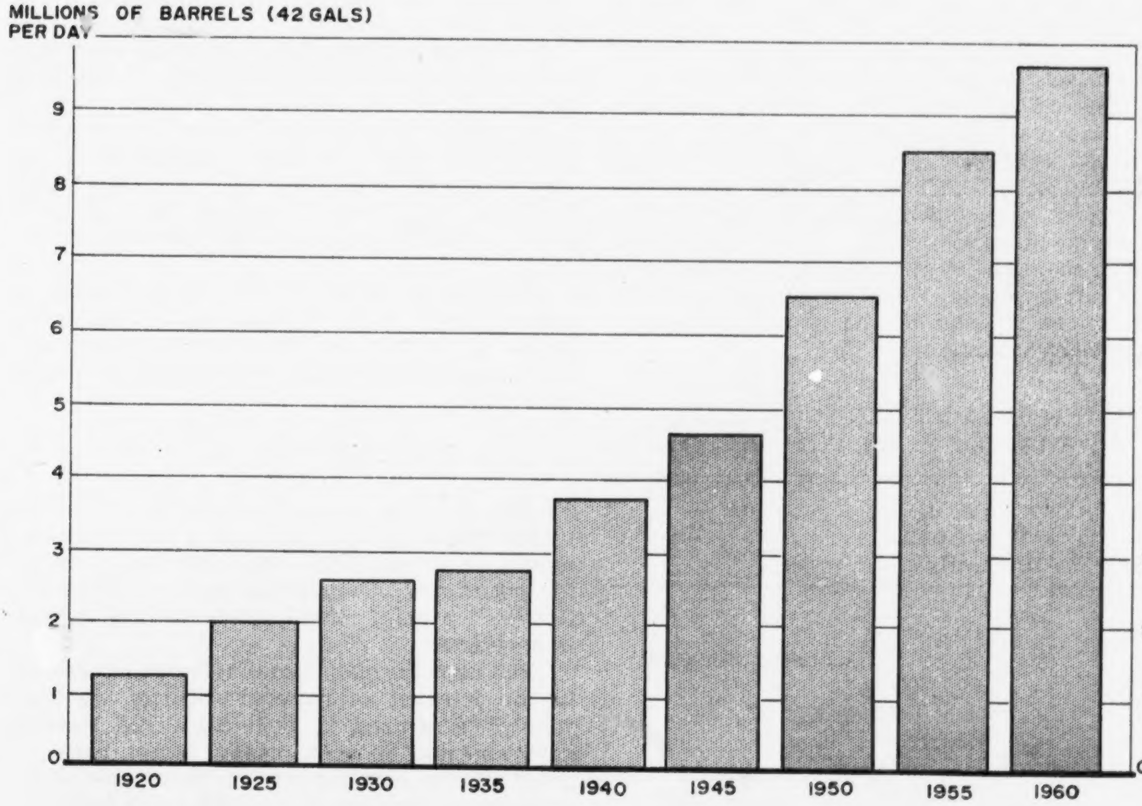

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Figure 1-2.—U. S. domestic demand of all liquid petroleum products, 1920-1960.

In 1941, the United States produced 4,000,000 barrels per day of crude oil, and according to estimates, had a domestic production capacity of 5,000,000 barrels a day. This provided a 25 percent cushion for emergency expansion between actual production and the maximum efficient rate of production. In 1951, the United States produced an average of 6,150,000 barrels/day and had a productive capacity of 6,750,000 barrels a day, including crude oil and condensate. This was a cushion of 600,000 barrels a day, or less than 10 percent as compared with 25 percent in 1941.

However, in 1963, the United States produced 8,641,000 barrels of liquid hydrocarbons per day and according to estimates for the same year the United States had a productive capacity of 11,500,000 barrels per day. This is a cushion in productive capacity of 2,859,000 barrels a day or 33 percent. Thus it is apparent that the United States had increased its cushion for production in case of emergency by a considerable amount, and at the same time has increased its yearly usage of petroleum products.

U. S. Refining Capacity

The actual supply of petroleum products depends not only on productive capacity, but also on the capacity of the refineries. At the end of 1963, total refinery capacity in the U. S. was 10,300,000 barrels per day, with actual crude runs averaging 8,687,000 barrels per day, giving an excess of 1,613,000 barrels per day, or 15.8 percent.

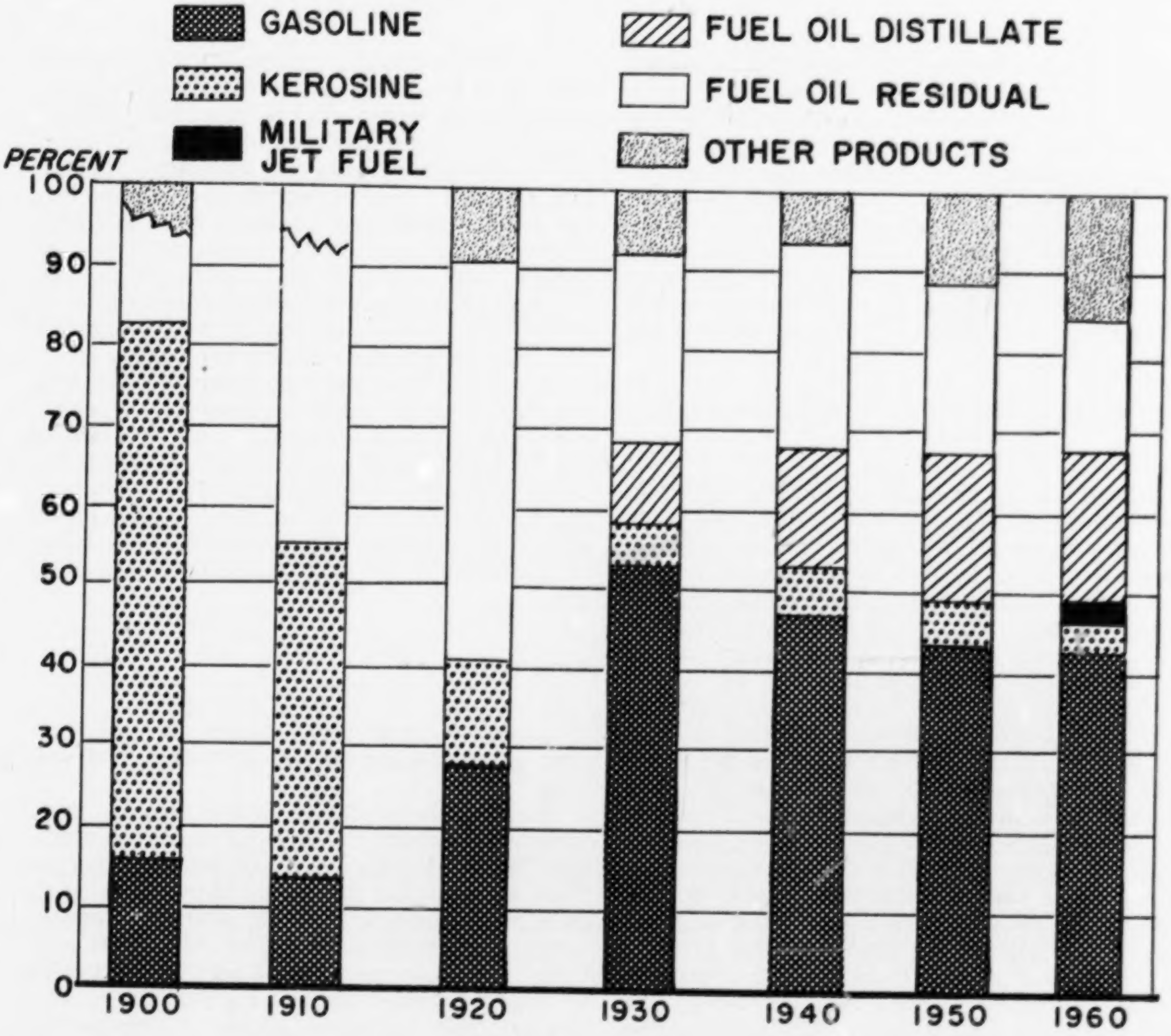

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Figure 1-3.—Comparison of Relative Volumes of Major Petroleum Products Consumed in the United States, 1900—1960.

RELATIONSHIP OF MILITARY TO CIVILIAN CONSUMPTION

It is clear that, in times of emergency, military requirements are high in priority. However, military successes depend largely on industrial production on the home front. Not a wheel in industry can turn without lubrication. Essential automotive transportation, air transportation, many railroads, and many components of industry are totally dependent upon petroleum for power. Heat, electricity, and gas, necessary to the health and essential needs of civilian war workers, depend, directly or indirectly, upon petroleum. During total war, civilian needs are inseparable parts of the total war effort. Therefore, wartime petroleum allocation must be based on the fact

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that there is only one available supply of petroleum, and that supply must be shared between military and civilian demands.

The total volume of petroleum products required by the military in peacetime is but a small fraction of the total demand. Just before the outbreak of hostilities in Korea, military requirements were only 4.9 percent of the total demand. At the end of Fiscal Year 1964, the military requirement amounted to 5.3 percent of the total U. S. production. This excludes all imports used within the United States by the military. However, military requirements in World War II amounted to 21 percent of total U. S. production.

MILITARY CONSUMPTION OF PETROLEUM PRODUCTS

To provide petroleum products in sufficient quantity to win World War II, almost seven billion barrels of oil had to be produced between December 1941 and August 1945. Nearly six billion barrels of this total came from the United States. This is one-fifth of all the oil that had been produced in this country since the birth of the industry in 1859.

During World War I, fewer than 200,000 barrels of oil products were supplied daily to the Allied Forces. At the height of the World War II effort in 1944-45, over 1 million barrels of petroleum products were delivered daily to the United States Armed Forces alone, as compared to a requirement of 780,000 barrels per day in 1964. During World War I, the air forces burned less than 3,700 barrels of aviation gasoline a day during the last 6 months of 1918. In World War II, one B-29 could consume as much as 10,000 gallons (approximately 238 barrels) in one long mission. Military gasoline consumption at the peak of World War II was 100 times that consumed by our overseas forces at the peak of World War I. During World War II, the American Army and Navy had 600 times as many motor vehicles as the American Expetitionary Forces had in Europe in 1918; the Navy and Merchant Marine had more ships and more tonnage than the combined merchant fleets of the world had after the first war. The Army and Navy operated 1,250 percent more planes before V-E Day than they did before Pearl Harbor. This was American armament alone; the planes, vehicles, and ships of our allies likewise multiplied in number and consumed proportionately huge quantities of oil products.

TYPES OF MILITARY PETROLEUM PRODUCTS

Modern warfare requires not only tremendous quantities, but a great variety of petroleum products. In World War II, more than 500 different petroleum products were regularly used by the Armed Forces. As military equipment has become more complex and specialized, specialized petroleum products have had to be developed for adequate performance. Then, too, modern war requires that equipment be used in climatic conditions ranging from the Arctic to the tropics, necessitating further adaptation of petroleum products for military use.

Although fuels and lubricants constitute the greatest bulk of military petroleum products, many others are indispensable. The major military petroleum products are grouped under seven headings for purposes of discussion: (1) liquid fuels, (2) lubricating oils, (3) gear lubricants, (4) greases, (5) corrosion preventives, (6) hydraulic fluids, and (8) miscellaneous products.

Liquid Fuels

Liquid fuels include: Automotive and aviation gasolines, jet fuels, kerosine, and fuel oils.

Automotive gasolines include military automotive combat and commercial gasolines. Combat Type I is for general all-purpose use and Type II, a special low temperature all-purpose gasoline, is for use in climates where temperatures are consistently below 32° F. It contains metal deactivators and oxidation inhibitors to improve long-term storage characteristics. Regular and Premium grades of commercial gasolines differ mainly in octaine number. Each grade is divided into three volatility classes to provide for local and seasonal climatic conditions.

Aviation gasolines include four grades of reciprocating engine fuels 80/87, 91/96, 100/130 and 115/145. Each grade is dyed a distinctive color. The Military Services have standardized on Grade 115/145, although some use is being made of the lower grades for small fixed-wing aircraft and some reciprocating engine helicopters and trainers.

Jet fuels include two grades, JP-4, a wide cut gasoline type and JP-5, a high flash point, kerosine type.

Kerosine for use in wick-fed lamps, stoves, and heaters.

Fuel oils include military and commercial grades of diesel fuels; burner fuel oils for vaporizing pot type burners and domestic heating; residual fuel oils, Military (Navy Special Fuel Oil) for steam powered naval vessels; and commercial for shore power plants.

Lubricating Oils

The varieties of lubricating oils are too numerous to list. Therefore, only a few examples are cited under three headings:

Automotive engine oils, which are used for lubricating internal combustion engines.

Aircraft lubricating oils, including aircraft instrument lubricating oils for the lubrication of aircraft instruments and electronic equipment; general purpose low-temperature lubricating oil; general purpose low-temperature lubricating oil for helicopter gear boxes and constant speed alternators.

Other lubricating oils, such as those for lubricating diesel engines; compounded lubricating oils for applications generally involving moisture or worm gears or wick feeds; clock and watch lubricants; oils for the lubrication of journal bearings of railway cars, steam and electric locomotives, and railway gun carriages; light lubricating oils for typewriters, sewing machines, and some shock absorbers; oils for lubricating reciprocating type refrigerant compressors; steam cylinder oils; and turbine oils.

Gear Lubricants

Gear Lubricants include those used for the lubrication of exposed gears, chains, and wire rope, and those for the lubrication of automotive gears, including hypoid type differentials and steering gears.

Greases

Greases include automotive and artillery grease for lubricating vehicle chassis, wheel bearings, and similar purposes; high temperature lubricating grease for ball bearings in searchlight equipment; water pump grease; rifle lubricating grease; ball and roller bearing grease; gasoline-and-oil-resistant grease; various types of grease for the lubrication of aircraft and associated equipment; grease for lubricating plug-type scrupper valves; and breech block grease.

Corrosion Preventives and Preservatives

Various types of petroleum compounds are used for the protection of critical surfaces in long-term storage; for displacing water from instruments and equipment; and for protection against high humidity and moisture condensation.

Hydraulic Fluids

Hydraulic fluids of various types are used in hydraulic brake systems, gun turrets, elevating mechanisms, and fork lift trucks.

Miscellaneous Products

The following are a few examples of petroleum products included in the miscellaneous group:

Paraffin waxes and petrolatums used in packaging and sealing rations, for dipping munitions to prevent rust and corrosion, and for similar uses.

Cutting oils are of various types. A fatty-oil-blend cutting oil (a mixture of mineral oils and lard oil) is used as a lubricant and cooling medium for machine cutting operations where a soluble oil is not suitable. A soluble cutting oil (a mineral oil which forms stable emulsions with water) is used as a lubricant and cooling medium in machine tool cutting and pipe threading operations and is also included in compound antifreeze water solution for flushing cooling systems preparatory to storage of equipment.

Solvents, some of which are used as paint thinners and for cleaning metal surfaces and bearings; and others which are used for dry cleaning clothes.

Insulating oils, some of which are used as the insulating and cooling medium for oil-immersed transformers, switches, circuit-breakers, and the like; and others which are used for X-ray high tension transformers.

Tail-packing compounds for torpedoes.

Asphalt, used for airstrips and for roofing.

Medicinal products, such as mineral oils; petrolatum jelly; anesthetics made from cyclopropane (an oil derivative); rubbing alcohol; and drugs containing alkyl chloride (a petroleum derivative) to retard bleeding.

Fungicides and insecticides, which are petroleum products to which chemicals have been added for killing qualities.

PETROLEUM LOGISTICS

Prior to World War II, logistic requirements of the Armed Forces were relatively small and were filled with comparatively little effort. For this reason, the tremendous logistic effort required for long, sustained campaigns was not visualized and very little provision was made for logistic organization or for the training of personnel in logistic skills. World War II highlighted this omission. The operational aspects of logistics proved to be an essential consideration in all phases of the war, even to the determination of strategy. Consequently, the word logistics became a familiar part of the vocabulary of the high commands. In elemental terms, logistics is the science of supplying what is needed, where it is needed, when it is needed.

Military petroleum requirements fall into one of two general categories: (1) probable wartime requirements and (2) current requirements. Probable wartime requirements are those necessary to support war plans and current requirements are those necessary for day-to-day operations.

Although the determination of requirements extends from the extremes of overall national and international requirements for the conduct of global war, down to the requirements for a small task unit engaged in a minor operation, the basic approach is the same. A large amount of statistical data is available to logistic planners. For example, consumption factors are used extensively in determining wartime petroleum requirements. These factors stem from several sources. One source is statistics on consumption of a given petroleum product by the various types of equipment. These factors also reflect the estimates of designers of the equipment. Usage data are used for determining petroleum requirements for stock replenishment (current requirements). These are average figures computed in various ways.

Navy logistic planners are interested primarily in availability of products, tankers, and storage facilities although other factors of indirect interest have far reaching effects on the fulfillment of Navy requirements. Navy strategic and mobilization reserve levels of petroleum products are computed, based upon planned deployment of forces. Petroleum product levels in turn influence the location and size of storage facilities to be leased or constructed and also influence methods of fleet resupply (mobile support, and advanced base support) under combat conditions.

Practical Information for the Petroleum Logistics Officer

While comparatively few officers are likely to become directly involved in the high-level logistics planning, many officers will be directly concerned, either as their primary assignment or as a collateral duty, with some phase of petroleum logistics at the operational level. Because of the nature of petroleum and its products, and because of the special handling required, these officers should understand at least these factors: product specifications, hazards of contamination and deterioration, the importance of quality surveillance, and safety precautions necessary in handling petroleum products.

PRODUCT SPECIFICATIONS.—Military specifications are stated in terms of physical and chemical tests which describe the required properties of products for military use. Although the petroleum logistics officer will not run tests on the products, he must be sufficiently familiar with specifications to be sure that he has the right product, or at least, one that can be used.

Military operations, particularly in overseas theaters in times of emergency, may present problems not normally encountered in the petroleum industry. For example: An operation which may be disrupted because of the lack of a particular petroleum product may be continued if a usable substitute is at hand. Conversely, the attempt to operate equipment with petroleum products which do not meet the required performance characteristics can halt operations. In consequence, it is of critical importance that personnel with sufficient understanding of petroleum products be available to weigh the factors of such operating situations and come up with sound decisions.

Hazards of Contamination and Deterioration.—Deterioration, frequently referred to as going "off spec," is the break-down of petroleum products caused by weathering or aging. The best protection against deterioration is the careful rotation of stocks, using the oldest stocks first. A contaminated product is one to which has been added some material not normally present, such as dirt, rust, water, or another petroleum product. The petroleum logistics officer must be alert to the fact that the use of a product which is "off spec" or contaminated may seriously damage or cause unsatisfactory operation of equipment.

Importance of Quality Surveillance.—The petroleum logistics officer must understand the causes of deterioration and contamination, and must eliminate these causes, so far as possible. He must understand the functions of technical officers who are charged with quality control, and the necessity of referring any products of doubtful quality to these officers. He must also know the proper methods of storage and transportation, know how to avoid losses from evaporation or leakage; and know the precautions to be taken to ensure maintenance of acceptable quality.

Safety Precautions.—The petroleum logistics officer must understand the hazards involved in handling petroleum products. To acquire an understanding of these hazards, he must know the physical characteristics of the products. He must be well aware that these properties necessitate special storage facilities, transportation equipment, containers, and the like. He must have, in short, a complete knowledge of the precautions required in handling petroleum products.

All these practical factors of petroleum handling can be applied with greater confidence and effectiveness if the officer concerned is reasonably well grounded in basic information about petroleum and its products. Consequently, succeeding chapters provide with a brief review of petroleum resources, properties of crude petroleum, petroleum production and the refining, measuring, sampling, testing, storage, and transportation of petroleum products.

THE STEPS IN PETROLEUM LOGISTICS

Three steps (types of action) are performed in petroleum logistics, namely: determination of requirements; procurement; and distribution. These steps are discussed briefly in the following sections.

Determination of Requirements

In the conduct of global warfare, a fundamental consideration is: what petroleum products, in what quantities, are needed to fight the war. This consideration embraces such extremes as the over-all national and international requirements down to the needs of a small task unit engaged in a minor operation. Consideration must be given to the fact that not a wheel in industry can turn without lubrication; that the Nation's transportation system would bog down without fuel; and that petroleum is the major source of lubricants and fuel for these purposes.

The type of war we fight is largely determined by the proper determination of requirements and the ability of the Nation to provide such requirements in the quantity needed, when needed, and where needed. A decision to conduct an offensive war can only be made when the material and manpower resources of the Nation are deemed adequate to provide the predetermined requirements of such a war. (As we have seen, petroleum is indispensable in modern warfare.) The determination of requirements for an offensive war is a responsibility and prerogative of military command. Many factors are naturally involved in the development of an estimate of petroleum logistical requirements. Some of the more important of these are:

1. A Consideration of the Strategic and Tactical Plans for Contemplated Operations.—These include the continued support of operations being currently conducted and the establishment and maintenance of lines of supply to all areas involved. In summary, it may be stated that only dangerous guesses result when requirements are not based on the dictates of specific strategic and tactical plans and/or current operations.

2. The State of Availability of the Resources of the Civilian Economy.—This includes a consideration of the amount of crude petroleum available, the Nation's production and petroleum refining capacity, transportation facilities, and the number of trained personnel. This factor is of great importance in the establishment of an initial base for calculations and in the formulation of a realistic time-table for prospective operations.

3. A Regard for the Needs of Allies and Possibly Some Neutrals, the Support of Whom

May be of Vital Concern to Continuation of Hostilities.

4. The Requirements of Military Government and Civil Affairs in Occupied Countries.

5. Balance and Timing.—Overall logistic efficiency is greatly affected by proper balance and timing and can be largely controlled in the first logistic step. For example, a major consideration in determining wartime requirements is the military need for specialized products having no relation to peacetime requirements. JP-5 jet fuel, a product needed in considerable quantities by the military services, is not a major refinery product in the civilian economy. The jet engine consumes enormous quantities of fuel which, though not produced for civilian consumption, must be refined according to very closely tailored specifications for military use. Similarly, the ships of the Navy require great quantities of another very closely tailored fuel, known as Navy Special. This is a blend of fuel oil designed for maximum speed, maximum utility in any climate, and minimum boiler fouling. This fuel also presents a problem in supply as it is not, under normal conditions, produced in great quantities.

Requirements for Stock Replenishment

The inventory control of bulk petroleum products for the Navy supply system is exercised by the Navy Fuel Supply Office. Inventory control is the process by which supply of material is balanced against the demand for material. Requirements for stock replenishment for the various petroleum items are determined by the requiring activity or by the Fuel Supply Office. Activities—both in continental United States and overseas—which determine their own individual stock replenishment requirements normally base them on past replenishable demand and established supply levels.

In general, overseas shore-based installations compute requirements and submit them to the Defense Fuel Supply Center on a form of requisition known as a "slate". The Operating Procedures for Bulk Petroleum and Coal Products, DSAM 4220.1, contains instructions for submission of slates.

Procurement

This step, coming between the determination of requirements and distribution, includes some of the elements of each of the other two steps. It is based on the determination of requirements and like that step is largely dependent upon the present or future availability of crude petroleum, finished petroleum products, facilities, and manpower. In the national defense structure, procurement is controlled primarily by the civilian elements.

Some of the factors involved in the procurement of petroleum are:

1. Material Specifications.—Petroleum specifications are fixed by the Department of Defense as a result of experience and research. These specifications must be adhered to by manufacturers. They must be sufficiently restrictive to ensure that products will meet the requirements of the equipment for which they are intended; on the other hand, if specifications are too restrictive, the ultimate cost of an item and the time required for its manufacture may be completely out of proportion to its benefit to the ultimate consumer.

2. Standardization.—Standardization is a vital companion to material specifications and to cataloging. The military services require an ever-increasing number of specialized types of equipment and therefore of specialized petroleum products. Recognizing that this makes the problem of supplying petroleum products more complex, the Department of Defense continually endeavors to combine the different requirements into joint petroleum specifications and cancels those specifications no longer required. A reduction in the number of products required simplifies the refining problems for industry and the logistics problems for the services.

3. Cataloging.—Cataloging of petroleum products, the essential factor of identification, also presents strong indicia of products susceptible to improved standardization and common use among the services. Cataloging comprises the operations involved in item identification, classification, and stock numbering; including the selection of authorized item names, the preparation of descriptive patterns and their use in establishing identification, and as an aid to establishing interchangeability and substitutability of items; and in recording and presenting data pertaining thereto, in a form which is understandable and usable in all supply operations.

4. Purchasing.—The actual negotiation of contracts for manufacture or direct buying and payment for material needs of the Armed Forces is obviously a direct factor in procurement. This is discussed in a later paragraph.

5. Material and Cost of Inspection.—This is a necessary function in procurement and assures the Government that all contractual specifications for petroleum products are met by manufacturers or dealers and at an equitable cost.

6. Priorities and Allocations.—Although often a source of irritation, priorities and allocations are of vital necessity in the scheduling of procurement and distribution of petroleum products. Only an intelligent application of priorities and allocations can ensure that the most essential petroleum needs of the Armed Forces will receive the precedence in procurement and distribution that they deserve.

7. Accumulation.—The accumulation of petroleum products at contractors' bulk storage plants, and at continental storage depots and ports represents the final phase of procurement and at this point overlaps distribution.

Purchasing

The Defense Fuel Supply Center, the single manager operating agency for petroleum, is responsible for the procurement worldwide, of all petroleum, petroleum products and commercial services requested by the military services. The military services are responsible for submission of Military Interdepartmental Purchase Requests (MIPR) (DD Form 448) to DFSC for the procurement of petroleum products and services.

The Defense Fuel Supply Center phases submission of requirements, consolidates requirements, analyzes the market, and determines patterns for phased placement of orders in such a manner as to assure meeting the needs of the military services at the lowest cost to the Government. Based on requirements received, proposals are solicited from industry. Resulting quotations and proposals are analyzed and contracts awarded in accordance with the Armed Forces Procurement Regulations. Normally either an indefinite delivery or a funded, firm quantity-type contract is issued. Contract administration matters affecting pricing, quantities, quality, or delivery schedules are reserved to the Defense Fuel Supply Center. Inspection and acceptance functions are performed by the Defense Contract Administration Services (DCAS) or as indicated by the terms of the contract. Local purchase of petroleum products may be authorized when the amount of any single item does not exceed $2,500 and no DFSC contract is desired by the military services.

Figure 1-4 shows DFSC procurement actions by percent of products purchased and figure 1-5 shows the total dollar value of DFSC contracts.

Distribution

Distribution begins with the accumulation of petroleum products at continental depots and ports; it ends with delivery of the products to the ultimate consumer. It leads from planning and procurement to the fighting forces and in general is concerned with the following factors:

1. Accumulation.—This involves holding or storage, either as strategic reserve or for specific operations. The stock levels set for various organizations or projected plans are built up and maintained for future employment—within the limits imposed by the type of petroleum product being stored—in this initial phase of distribution. The foundation for accumulation and distribution of material needs in the Navy is largely the outgrowth of wartime experience with these factors.

2. Construction.—Accumulation implies construction or the providing of extensive storage facilities, specifically designed for petroleum products, in both the continental United States and the area of operations.

3. Distribution Agencies.—Distribution agencies, both civil and military, control the petroleum transportation needs of the Armed Forces from accumulation points to consumer. Products may be transported in bulk by tanker, tank truck, tank car, or pipeline, or as packaged products handled as regular cargo. To ensure that required products are supplied when and where needed, it is essential that distribution agencies maintain close liaison and relations with those concerned with operational planning and execution. One agency in distribution of petroleum products is the Military Sea Transportation Service which, in close cooperation with the Defense Fuel Supply Center and the three military services, schedules and transports petroleum products by tanker for the military services.

4. Operation of Continental and Overseas Ports and Fuel Depots.—The operation of such ports and depots follows transportation and has an intimate relation to storage, shore construction, fuel dispensing facilities, and shipping and shore transportation control.

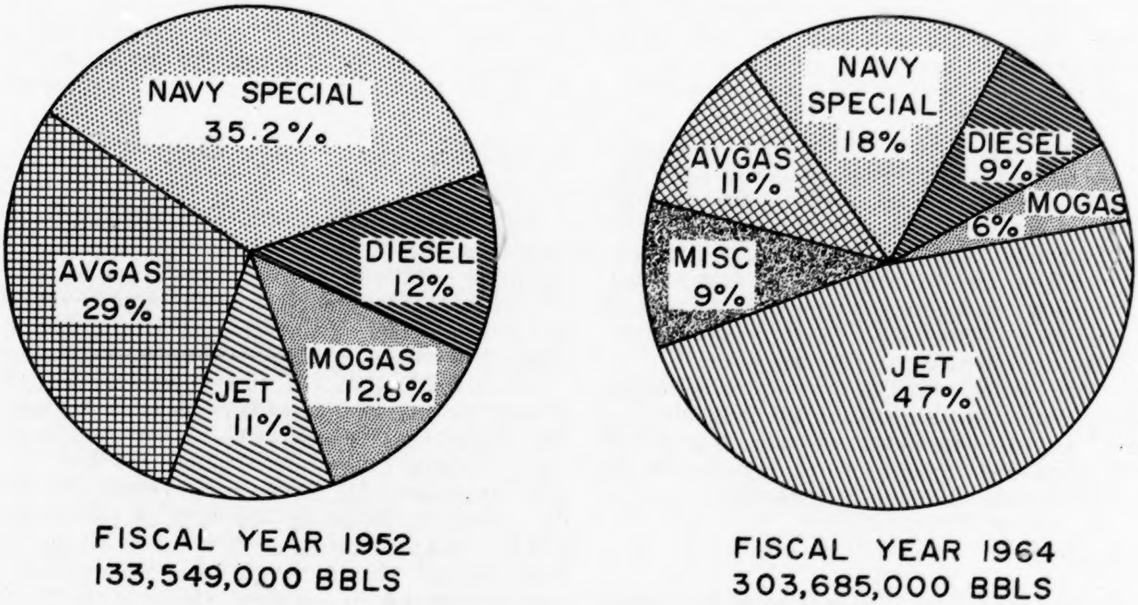

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Figure 1-4.—DFSC procurement actions by percent of products purchased.

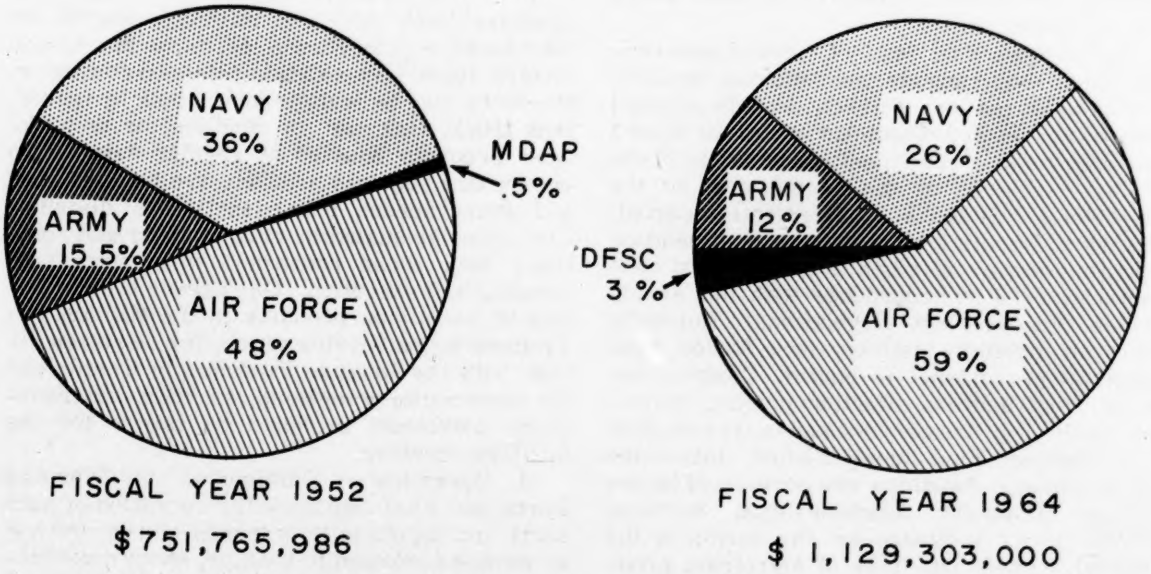

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Figure 1-5.—Total dollar value of DFSC contracts.

CHAPTER 2

PETROLEUM RESOURCES

In order to obtain finished petroleum products, it is necessary to consider the occurrence of crude oil, its production, and the refining of the crude oil. All of these phases are important and all are interrelated. Balance must be maintained among these various phases of the petroleum industry; balance must also be maintained between domestic and foreign supply.

For several reasons it is of first importance that the United States preserve a dynamic, progressive, and enterprising domestic petroleum industry. Strategically it is essential that there be a complete petroleum industry located within the borders of the United States. Such an industry would be the safest source of supply for petroleum products if it were necessary for the United States to fight a defensive war, for then the Nation would be dependent upon domestic sources alone.

While such domestic supply must always be of primary consideration, foreign supply also is very important. Should it become necessary for the United States to fight a foreign war again, it would become necessary to augment domestic supplies of petroleum with supplies from other sources in the Western Hemisphere. In addition, the building up of the total military and economic potential of other free countries is an important factor in our national defense. Such a building up, in turn, depends in large part on the development of foreign petroleum resources in friendly nations. It is obvious that the domination of foreign petroleum sources by unfriendly nations would greatly weaken the Nation's strategic position.

OCCURRENCE OF OIL

According to estimates of geologists, approximately 15 million square miles of the earth's surface consist of geologic formations which are favorable for the accumulation of oil. About 10 percent of this area lies in the United States. It must be remembered that these indicate possible oil accumulations and do not indicate the actual discovery of oil. Estimates of possible oil deposits are extremely hypothetical, since many variables are unknown, but it is of interest to consider some of these estimates. There have been many such estimates ranging from 13 billion barrels to over 1900 billion barrels left to be found within the United States. Generally speaking, the estimates of knowledgeable geologists and engineers fall within a narrower spread of 175 to 400 billion barrels of oil left to be found in the United States, and would be in the form of total ultimate reserves of crude oil or hydrocarbons in liquid form. Assuming a conservative 250 billion barrels for an ultimate figure, production to date and proved reserves when added together have been estimated to be about 110 billion barrels at the end of 1962, leaving a remainder of approximately 150 billion barrels to be found. Proved reserves means the total known quantities of oil in fields already discovered which, under existing conditions, can be produced by present day methods. Historically, estimates of total crude oil resources have always been far too low; however, it is obvious that there are abundant supplies of hydrocarbons awaiting discovery in this country.

In the United States, actual production of barrels of crude oil has always been considerably less than the total barrels of proved reserves. It is vital that this ratio be maintained so that a cushion of petroleum reserves is ensured. Continuous exploration, drilling, and control of production is necessary to maintain an adequate reserve, and to replace oil reserves which are lost by the depletion of older fields.

Statistics on proved reserves of crude oil in the United States are given in table 2-1. Proved reserves for the free world are shown in table 2-2.

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Table 2-1.—Proved Reserves of Crude Oil in the United States

(Billion Barrels—Rounded)

Year	Estimated Proved Reserves At End of Year	Production During Year	Ratio: Reserves Production
1950	25.3	1.9	13.3
1951	27.5	2.2	12.5
1952	28.0	2.3	12.2
1953	28.9	2.3	12.6
1954	29.5	2.3	12.8
1955	30.0	2.4	12.5
1956	30.4	2.6	11.7
1957	30.3	2.6	11.6
1958	30.5	2.4	12.7
1959	31.7	2.5	12.7
1960	31.6	2.5	12.6
1961	31.8	2.5	12.7
1962	31.4	2.6	12.0
1963	31.0	2.7	11.5

A member of the U. S. Geological Survey in 1963 estimated that worldwide recoverable reserves of petroleum are about 300 billion barrels, and undiscovered potential resources are about another 4 trillion barrels. It is emphasized that these figures are much higher than most other estimates made by industry sources.

None of the above figures include oil found in bituminous rocks such as those in Athabasca, Canada, or the western United States. There are estimated to be about one trillion barrels in undiscovered and marginal reserves, and 40 billion discovered and recoverable. Shale-oil reserves, most of which are in the United States, are estimated at 150 billion barrels known, and 14 trillion barrels undiscovered and marginal in nature.

OIL RESOURCES

In addition to petroleum resources within the United States, petroleum logistic planners must consider foreign oil resources. If the United States could depend on oil reserves of the Middle East in a time of emergency, the task of fueling a war machine would be relatively easy. Some plans, however, do not include availability of oil from this area. Still, the potentialities of the Middle East, as well as other areas, must be considered in any strategic plan, and also in planning the logistical support of friendly nations.

At the end of 1964, the free world proved reserves were still essentially as shown for 1963 in table 2-2. The most important nations with regard to proved oil reserves were apportioned as follows: Kuwait 20%, Saudi Arabia 19%, Iran 12% United States 11%, Iraq 8%, and Venezuela 5.4%.

Changes in petroleum reserves and also changes in political policy are constantly taking place, and this fact must be remembered when considering the future of petroleum reserves. During 1964 the eastern half of the world eclipsed the west in energy consumption—especially oil. The Eastern Hemisphere is the major growth area for oil and will continue to be. However, the large energy users of the Asia-Pacific area and Europe are closing the gap between oil consumption and crude supplies available. There is still a large oil surplus, but currently refining capacity is increasing faster than production of crude oil.

The free world oil picture at the end of 1964 shows only an 8 percent increase in reserves over 1963, but still represents approximately 9 billion barrels of newly-available oil supply. The most spectacular increases came from Africa, oil's newest important producing area. In addition to important discoveries in North Africa, Nigeria is rapidly increasing its oil potential. Although great interest is focused on Africa, the Middle East continues to increase in importance.

The Western Hemisphere in recent years has not progressed as rapidly as other oil-producing areas. Latin America as a whole is just about maintaining its reserves. Columbia may prove to be more important in the future and Venzuela may open new acreage concessions which could further accelerate the development of her petroleum industry. There is little likelihood that the Western Hemisphere area will ever regain its once dominant position in all sectors of the oil industry and it is lagging behind other areas of the world in expansion.

Europe is a rapidly expanding industrial area and major economic growth is expected to

Table 2-2.—Free World Proved Reserves

(Billion Barrels—Rounded)

	1950	% of Total	1956	% of Total	1963	% of Total
United States	25.3	28.8	30.4	14.1	31.0	10.7
Venezuela	9.5	10.8	14.0	6.5	17.0	5.8
Canada	1.2	1.4	2.8	1.3	4.9	1.7
Other West. Hem.	1.8	2.1	3.5	1.6	6.5	2.2
Total W. Hem.	37.8	43.1	50.7	23.5	59.4	20.4
Free Europe	0.3	0.4	1.4	0.7	2.2	0.8
North Africa	0.2	0.2	0.5	0.2	14.0	4.8
West Africa	NIL	-	NIL	-	1.0	0.3
Middle East	48.0	54.7	156.0	72.4	204.0	70.2
Other East. Hem.	1.4	1.6	6.9	3.2	10.2	3.5
Total East Hem. (Excl. Communist Bloc)	49.9	56.9	164.8	76.5	231.4	79.6
Total Free World	87.7	100.0	215.5	100.0	290.8	100.0
Increase - 1956 vs 1950			146%			
Increase - 1963 vs 1956					35%	
Increase - 1963 vs 1950					232%	

continue in the future. This is especially true in energy consumption. European oil production accounts for only a fraction of its needs so it is an area largely dependent on imports. Although a coal-producing area, coal is rapidly losing ground to oil. Natural gas is highly important, sparked by the discovery of one of the world's biggest reserves in the North Sea area.

PRODUCTION

In considering the world's petroleum regions, various groupings are possible. For the purposes of this text, the groupings used are as shown in tables 2-2 and 2-3. The United States, Venezuela, and Canada are part of the Western Hemisphere but are listed separately because of their importance in overall planning to meet United States requirements.

Middle East

The Middle East is the world's chief petroleum producing region and also has approximately two-thirds of all proved reserves in the Free World. This area includes the lands bordering the eastern end of the Mediterranean, the Caspian, Red, and Black Seas, and the Persian Gulf. The vast accumulations of Saudi Arabia, Iran, Iraq, Kuwait, Bahrein, Qatar, and others are in this region, and it is probable that more oil will eventually be produced in this region than anywhere else in the world. Even without thorough exploration, the Middle East, at the end of 1964, had proved reserves in excess of 212 billion barrels, the majority of which has been discovered within the past decade. Commercial crude production in this region began in Iraq in 1908, in Iran in 1934, and in Saudi Arabia in 1940. Current production of crude oil in the Middle East is about 780,000,000 barrels a day.

Western Hemisphere

Second in importance with regard to both reserves and daily production of petroleum is the Western Hemisphere. Total proved reserves in this area amounted to about 65 billion barrels, mostly in the United States, Venezuela, and Canada. The United States leads in proved reserves with over 34 billion barrels at the end of 1964 and also in production with over 7,600,000 barrels per day. Within the United States important areas with crude reserves, other than the Gulf Coast, are the Mid-continent areas, west coast, and local areas in the Rock Mountain Cordillera.

Oil and gas have been found in most of the States of the United States, but as shown in figure 2-1, the States which lead in the actual production of crude oil are Texas, Louisiana, California, and Oklahoma. A California oil field is shown in figure 2-2.

Venezuela is second with proved reserves of 17 billion barrels per day. Canada is third with proved reserves of over 5 billion barrels and production of over 700,000 barrels per day. Other nations that participate significantly in the production of crude petroleum are Mexico, Argentina, Columbia, Trinidad, and Brazil.

The crude oil refining capacity is largely centered in the United States with a capacity of nearly 11,000,000 barrels per day. Venezuela and Canada each have a capacity of about 1,100,000 barrels per day.

North Africa

A new significant oil-producing area has recently attained the third place position in world importance, not only in proved reserves but in daily production. This area is North Africa, and includes Egypt, Algeria, Libya, and Tunisia. First production in North Africa was

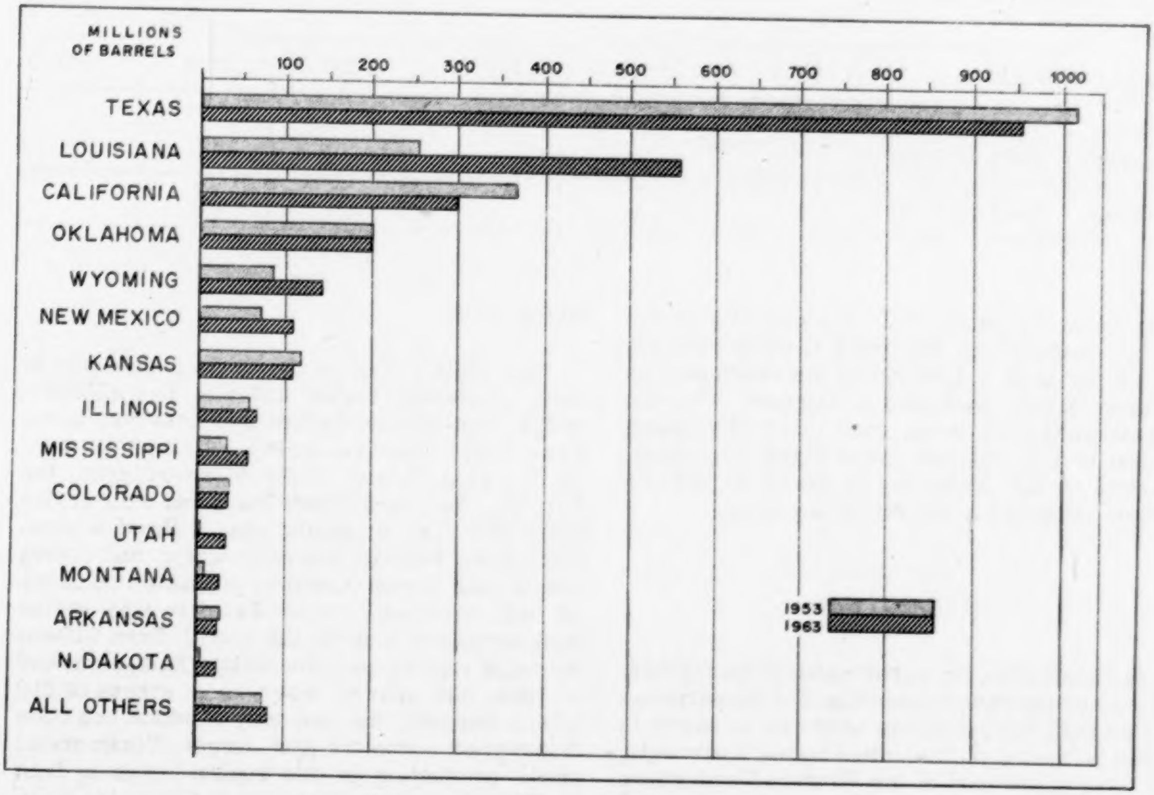

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Figure 2-1.—Production of crude petroleum in the United States (1953-63) by states.

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Figure 2-2.—A California oil field.

accomplished in late 1956, with the greatest development occurring in the 1960s. By the end of 1964 total proved reserves in North Africa approximated 18 billion barrels, and daily production averaged over 1.5 million barrels of crude petroleum.

Other Significant Areas

Areas in the free world of lesser importance but producing significant quantities of crude petroleum include:

1. Africa (other than North Africa) in such locales as Angola, Congo, Gabon, Senegal, and Nigeria, with the latter showing promise of considerable further development. Proved reserves are almost 1.5 billion barrels, and daily production is over 200,000 barrels.

2. Asia-Pacific Area—The chief fields are in Brunei, Burma, India, Indonesia, Malaysia, et cetera. Exploration is still far from complete here, but proved reserves are on the order of 11.5 billion barrels, most of which have been determined in the last 10 years. This producing region has an average daily production of over 600,000 barrels of crude oil.

3. Australia is a new area of production, still relatively small in reserves and yield, but of probable great increase in importance. The first oil was discovered in late 1961 and several additional producing areas have been found since. At the end of 1964 proved reserves totaled 50 million barrels.

4. Countries in Europe that have some production are Austria, France, Italy, Netherlands, Spain, United Kingdom, and West Germany. Total proved reserves amount to 2 billion barrels and daily crude production averages nearly 400,000 barrels daily.

At the end of 1964 the Communist Bloc was estimated to have proved reserves of about 31 billion barrels and daily production of 4.7 million barrels. The areas of the Communist Bloc are extremely large and wide-spread and every prospect exists for great petroleum reserves to be discovered. Production is expected to continue to increase rapidly. The chief fields are in U.S.S.R., Roumania, Red China, and Hungary.

PETROLEUM PRODUCTS DEMAND IN THE UNITED STATES

Since the first oil well was drilled in 1859, petroleum has become increasingly important—first as a source of light and later as a source of power and heat. Today, the military forces get the major part of their energy requirements from petroleum and its associated products.

Total United States demand for petroleum products continues to gain. For the first half of 1964, the total domestic demand was up 2.7 percent for an average of over 11,000,000 barrels per day. A detailed discussion of the demands for all major products is beyond the scope of this text, but summaries of a few market trends will serve to show the increasing demand. Total daily world consumption and production of petroleum at end of 1963 (excluding the Soviet Bloc) are shown in table 2-3.

Table 2-3.—Production and Consumption of Oil at the End of 1963
(Excluding Communist Bloc)

(Million Barrels—Rounded Per Day)

	Production	Consumption
United States	7.6	10.7
Venezuela	3.4	.2
Canada	.8	.9
Other W. Hem.	1.1	1.6
Total W. Hem.	12.9	12.4
Free Europe	.4	5.3
North Africa	1.1	.2
West Africa	.1	.2
Middle East	7.7	.7
Other East Mem.	.6	1.0
Total East Hem. (Excl. Communist Bloc)	9.9	7.4

Gasoline

Domestic consumption of gasoline during the year 1964 was up 3.9 percent over the previous year. Daily usage of gasoline averaged 4,653,000 barrels. Aviation gasoline usage totals about 130,000 barrels per day or only 3.5 percent of all gasolines. Demand for aviation gasoline is decreasing steadily because of the increasing use of jet fuels in commercial aircraft. Military consumption of aviation gasoline also is maintaining a downward trend.

Jet Fuels

Commercial aviation use of jet fuels is steadily increasing; in fact, some authorities believe that by 1970 there will be no domestic air lines using piston engines which require gasoline for fuel. Military jet fuel usage during 1964 averaged 330,000 barrels per day, an increase of 2.8 percent over the previous year. Commercial jet fuel consumption averaged 228,000 barrels per day, an increase of 10.7 percent over 1963, reflecting the rapid change to turbine-powered aircraft by the commercial air industry.

Distillates

The use of diesel equipment on the railroads, the highways, in construction equipment, and the like continues to expand.

Residual Fuels

Heavy bottom products known as residual fuels are used by utilities as a power source and also in ship bunkers. Less and less of this type fuel is becoming available domestically, as new refining processes make it possible to obtain higher yields of gasoline, jet fuels, and distillates. Imports are therefore necessary to ensure a sufficient quantity of residual fuels.

Import and Export Demands

United States oil imports of crude oil and finished products have tended to increase while exports of both have decreased. The continuing increase in overseas refineries capable of producing lubricants and other specialized products will undoubtedly cause further reductions in exports from the United States.

CONSERVATION

In the early days of the United States oil industry, when our oil resources appeared to be plentiful, many of our fields were almost destroyed. This may be attributed to the greed of operators who wanted to get the most oil possible in the quickest way, and to lack of knowledge concerning the most efficient operation of oil fields. It is estimated that by mismanaging fields in the past, we lost about 80-90 percent of the oil which could have been recovered by more efficient methods; today, however, we are getting 80-90 percent of the oil.

In recent years much progress has been made in designing and operating secondary recovery projects for the recovery of oil from previously depleted fields. The oil made available by secondary recovery methods has in recent years added materially to the Nation's reserves. Many organizations such as the American Petroleum Institute and the Pennsylvania Grade Crude Oil Association have initiated and are continuing to carry on research and experiments to increase the amount of oil recovered by these methods.

In the past, large quantities of gas, produced with the oil, were released into the atmosphere or burned. Today some of these gases are sold for domestic and industrial fuel. Other gases are used in the manufacture of various petroleum products.

Oil was also lost when, in excess of current needs, it was brought to the surface and stored. Inadequate storage facilities resulted in loss through seepage and evaporation. Also, in many cases, wells were operated beyond their most efficient production rates. Such practices are no longer permitted and production is regulated.

Oil fields usually reach their maximum rate of production within a few years after discovery, but this behavior may be modified by artificial restrictions. Prorationing is one practice which has been applied in many fields, particularly during periods of flush production. This practice restricts early production, delays development, and defers the time of peak productive capacity.

FUTURE OIL SUPPLY

"How long will United States oil reserves last?" This is a question frequently asked, particularly in view of the increasing demand for petroleum products.

On numerous occasions, fear has been expressed that we are running out of oil. Shortages were created during World Wars I and II, but these were balanced in each case by intensive postwar exploration and drilling. Although proved reserves are being diminished by the withdrawal of oil from producing fields, they are simultaneously being increased by discoveries of new fields, by improved recovery methods, and by finding that known fields are larger than at first supposed. Nevertheless, when shortages occur, many tend to view the future with alarm.

So far we have never run out of oil. In times of shortages, prices have increased, thus giving incentive to the petroleum industry for increased drilling activity. This, in turn, has resulted in the discovery of new reserves which, for many years, have slightly exceeded the production of oil. Total known reserves have ranged between 10 and 20 times the annual production. This situation can be expected to continue as long as there are unexplored, untested geological formations favorable to the accumulation of oil.

As we have seen, our supply has been and continues to be augmented by imports of foreign oil. Yet it is obvious that the supply is not limitless and that new oil fields are becoming more difficult and more expensive to find.

When eventually a period of undersupply is finally reached, new reserves will still be found but in a slowly diminishing amount. Many persons feel that before this period is reached, a synthetic fuel industry must be stimulated.

SYNTHETIC LIQUID FUELS

Synthetic fuels is the term commonly used to indicate fuels manufactured from sources other than crude petroleum. It refers particularly to the manufacture of fuels from coal and shale. At the present time, oil from shale and coal is not being produced commercially because of the cost. The Bureau of Mines, however, has several experimental plants for making such fuels and the Navy administers oil shale reserves for this purpose. The Bureau of Mines' synthetic liquid fuels program has forged ahead, and important technical advances led the way to improved methods of converting coal and oil shale into liquid fuels.

The increasing demand for petroleum products and the rising cost of finding new petroleum, coupled with America's growing dependence on imports and the unsettled international situation, have continued to emphasize the importance of the Bureau of Mines' program. It is considered that the supplementing of natural petroleum with synthetic liquid fuels will not only conserve the Nation's petroleum reserves, but will also bring into greater use its tremendous reserves of coal, as well as the vast deposits of oil shale for which no other practical use has yet been found. (The Bureau of Mines estimated that there are 92 billion barrels of shale oil and 3 trillion tons of coal available in this country.)

It is the opinion of many that through the development of commercial synthetic liquid fuels, the United States can obtain oil products from its great inland reserves of coal and oil shale to supplement petroleum in any quantity that may be necessary. The use of raw materials from such deposits would be of highest importance in wartime, when shipping lanes are menaced by the enemy.

Trends in petroleum refining also indicate the need for the development of a synthetic fuel industry. As we have seen, refiners are increasingly emphasizing the production of higher-grade products and the petrochemical industry is a growing one. For this reason, the future United States demand for fuels may outstrip their manufacture. Many experts feel that the Nation's future supplies of fuels can best be met by synthetic fuels. Moreover, it is their opinion that petroleum will become too valuable to burn for fuel and that our petroleum resources can be utilized most effectively in the manufacture of petrochemicals.

Through the use of prototype plants, research and technology have advanced to the point where the cost of shale oil is only slightly greater than the cost of crude oil. These plants, as the first step in the development of a synthetic fuels industry, serve a threefold purpose:

1. They provide a basis for future rapid expansion of the shale oil processes.
2. They will aid in conserving natural petroleum and reducing America's dependence on imports by hastening utilization of abundant domestic raw materials for the production of liquid fuels.
3. They will lead to the production of important chemical products for commercial use.

Although opinions differ as to when synthetic fuels from coal and oil shale will be needed to supplement domestic oil and imports, or when synthetic oil can compete with natural petroleum, national defense needs dictate that we avoid unnecessary risk in a commodity as vital as oil. There is general agreement that the United States eventually will supplement domestic and imported petroleum with synthetic oil, and the necessary technology must be ready for use without delay.

As the cost of making oil from shale and oil decreases, it is anticipated that synthetic fuel will become a substantial supplement to our crude oil supply.

CHAPTER 3

PROPERTIES OF CRUDE PETROLEUM

Crude oil varies in color from black, through various shades of brown and green, to a light amber. In rare instances, it may be almost colorless. The more important gaseous forms of naturally occurring petroleum are methane, ethane, propane, and butane. Natural gas, which is used as an industrial and domestic fuel, is chiefly methane with some ethane.

Gaseous forms of petroleum can be converted into liquids by changes in temperature and pressure. For example, propane, and butane, which are gases under normal conditions, can be converted into liquids by the application of pressure. Known as liquefied petroleum gases, they are used in rural areas for cooking and heating, and in urban areas as an enricher for manufactured gas.

Similarly, crude oil—a liquid consisting of many compounds—may be cracked by the application of heat to give many gaseous compounds. This process is used in refining and is described more fully in chapter 5.

Crude oil is flammable and its gases are frequently explosive. The lighter, more volatile liquids are readily ignited and will burn completely to give carbon dioxide and water.

Crude petroleum is a complex mixture of various chemical compounds, commonly known as hydrocarbons. Traces of nitrogen, sulfur, oxygen, and metals such as vanadium may also be present. Crude oils containing elemental sulfur and certain sulfur compounds, such as hydrogen sulfide and mercaptans, are known as sour crudes. These crudes usually have a vile or nauseating odor.

Hydrocarbon compounds consist of hydrogen and carbon. However, these compounds differ in their carbon and hydrogen ratio, in their molecular weight, and in their molecular structure. Before considering the various types of hydrocarbons, it is necessary to review those chemical principles which are basic to an understanding of the discussion.

CHEMICAL PRINCIPLES

Chemical Element

A chemical element is a pure substance which cannot be subdivided by ordinary chemical means. Examples of chemical elements are hydrogen, carbon, oxygen, and sulfur.

Atom

An atom is the smallest particle of an element which is capable of entering into a chemical reaction.

Molecule

A molecule is composed of atoms and is the smallest division of any chemical compound that retains the properties of that compound.

Compound

A compound is a chemical combination of two or more chemical elements in definite proportions by weight.

Isomeric Compounds

Isomeric compounds are compounds composed of the same elements, united in the same proportions by weight, but differing in one or more properties because of differences in molecular structure.

Valence

The valence of an element is the combining capacity of one of its atoms as compared with that of an atom of hydrogen. In figure 3-1, the valency bond is represented by a hook. An atom of an element having a valence of one can combine with an atom of another element having a

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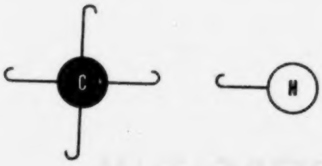


132.12
Figure 3-1.—The valence of hydrogen is one. The valence of carbon is usually four.

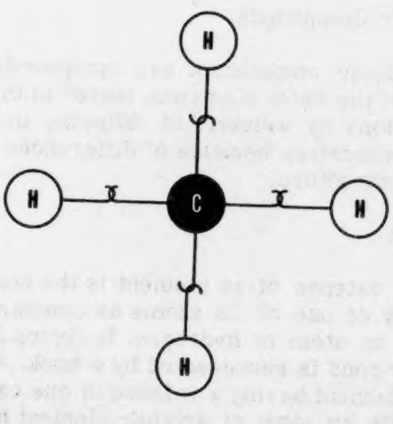
valence of one; an atom having a valence of four can combine with four atoms of an element having a valence of one.

Hydrogen has a valence of one; carbon usually has a valence of four. Therefore, one carbon atom can combine with four hydrogen atoms to form a hydrocarbon having the formula CH_4 (methane). Its structure is shown in figure 3-2.

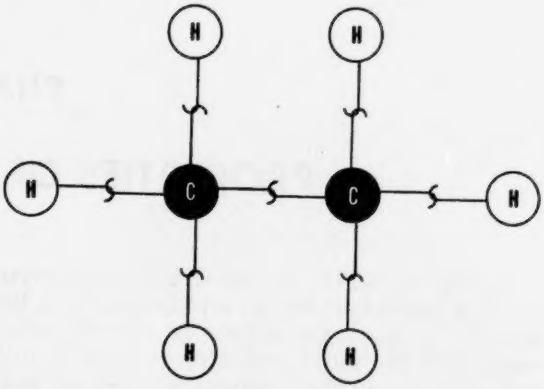
Saturated Hydrocarbons

When an atom of carbon has combined with four atoms of hydrogen, it cannot take up any more atoms because its four valency bonds are satisfied. When the valency bonds are satisfied, the hydrocarbon is said to be saturated.

Two carbon atoms can also combine with each other and with hydrogen to form a compound having a carbon-to-carbon single bond, as shown in figure 3-3. Here, too, the valency bonds are fully satisfied, either by the carbon-to-carbon bond or by hydrogen atoms.



132.13
Figure 3-2.—Molecule of methane, CH_4.



132.14
Figure 3-3.—Molecule of ethane, C_2H_6—a saturated hydrocarbon.

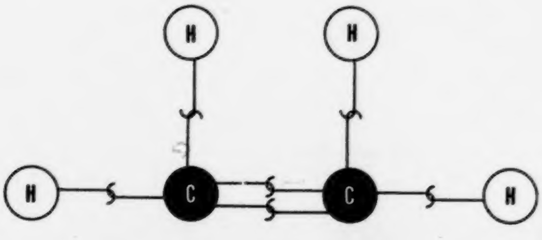
Because the valency bonds of saturated hydrocarbons are fully satisfied, these hydrocarbons are relatively stable.

Unsaturated Hydrocarbons

A hydrocarbon having a deficiency of hydrogen is called unsaturated. Because of the deficiency of hydrogen atoms, the unsatisfied valency bonds of one carbon atom will hook onto the unsatisfied valency bonds of another carbon atom to form a double or triple bond. However, this may be considered a temporary bonding because the extra bonds will, under certain conditions, separate readily to join with other elements which become available. Ethene (commonly called ethylene) is an example of an unsaturated hydrocarbon. Its molecular structure is shown in figure 3-4.

As illustrated, a molecule of ethene contains two carbon atoms which are linked by a double bond. Thus, each carbon atom has one valency bond which is not satisfied by another element, but which is temporarily satisfied by the carbon-to-carbon linkage. These bonds—one from each atom—will readily break apart under certain conditions to combine with some other chemical element, such as oxygen.

Since unsaturated hydrocarbons have bonds which are available for combining with other chemical elements, they are less stable than saturated hydrocarbons. Thus, a gasoline consisting of a high percentage of unsaturated hydrocarbons has a tendency to form lacquers, gum, and sludge by oxidation (combining with oxygen).



132.15
Figure 3-4.—Molecule of ethane (ethylane) C_2H_4—an unsaturated hydrocarbon.

TYPES OF HYDROCARBON COMPOUNDS

Hydrocarbon compounds may be classified according to their carbon and hydrogen ratio and according to their structure. The four general types of hydrocarbon compounds found in petroleum are: (1) paraffins; (2) naphthenes; (3) olefins; and (4) aromatics.

Paraffins

The hydrocarbons which are richest in hydrogen are called paraffins. These are saturated hydrocarbons which derive their name from the Latin parum affinis, meaning small affinity. As previously mentioned, saturated hydrocarbons are relatively stable.

Physically, the more common paraffins are liquids, but the series also includes those which are gases at normal temperature, and those which are semisolid or solid. The product known as paraffin wax belongs to this series.

According to the Geneva system of nomenclature—which is internationally accepted by chemists—fully satisfied hydrocarbons having single bonds in their molecules are given names ending in ane. Common examples are methane, ethane, propane, butane, pentane, hexane, and octane.

The formulas of paraffins are easy to recognize since the number of hydrogen atoms is always two more than twice the number of carbon atoms (C_nH_{2n+2}). A selected list of paraffinic hydrocarbons, with their formulas, is given in Appendix B.

The molecular structure of paraffinic hydrocarbons is characterized by the open-chain arrangement of the carbon atoms. These open-chain hydrocarbons may be subdivided into two groups; namely, straight-chain paraffins and branched-chain paraffins.

Straight-chain paraffins are those in which the carbon atoms are arranged linearly as shown in figure 3-5. These paraffins are called normal paraffins. They are, in general, the most stable in the entire hydrocarbon family at ordinary temperatures and do not react readily with strong acids or alkalies. However, they have a low octane value.

A branched-chain paraffin, 2-methyl propane (commonly called isobutane) is shown in figure 3-6. It will be noted that normal butane and 2-methyl propane (isobutane) have the same formula although their molecular structure is different. Since 2-methyl propane is composed of

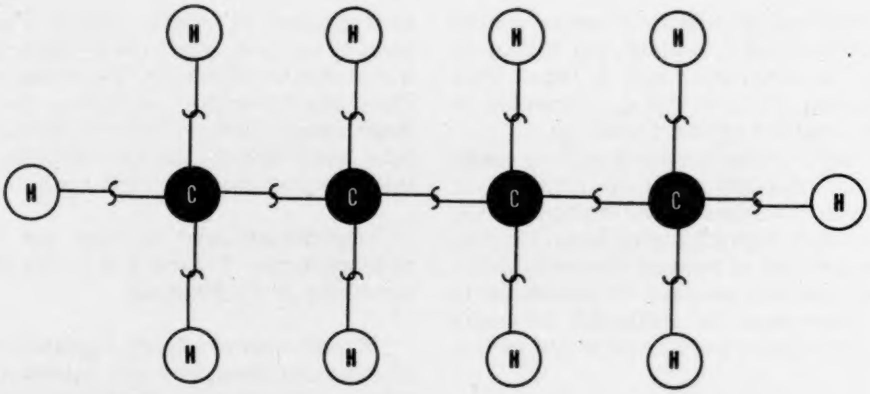


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Figure 3-5.—Molecule of normal butane, C_4H_{10}—a straight-chain, paraffinic hydrocarbon.

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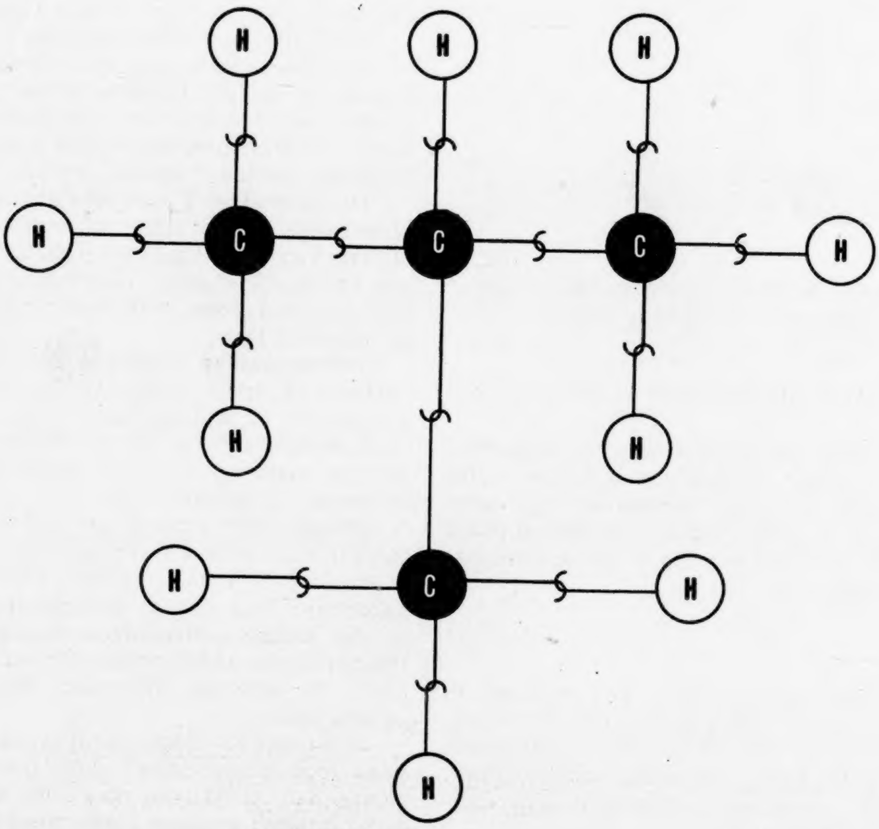

Figure 3-6.—Molecule of 2-methyl propane (isobutane) C_4H_{10}—a branched-chain paraffinic hydrocarbon.

132.17

the same number of elements as butane, united in the same proportion by weight, but differs in structure, it is isomeric with butane. This chemical property is, therefore, expressed in common nomenclature by the prefix iso.

Branched-chain paraffins are found to a small extent in natural gas and crude oil. Compounds of this type, with from five to nine carbon atoms, are very valuable in high antiknock fuels. Whereas the octane number of normal butane is relatively low, the octane number of isobutane is high. This difference in antiknock property is due to the difference in molecular structure.

Naphthenes

The molecular structure of naphthenic hydrocarbons is characterized by the closed-chain arrangement of carbon atoms. That is, the two ends of an open chain are joined together, forming a cyclic structure, as shown in figure 3-7. This characteristic structure is indicated in their nomenclature, as cyclobutane, cyclopentane, cyclohexane, and cycloheptane. As a series, they are sometimes called cycloparaffins.

Naphthenes may or may not be saturated hydrocarbons. Figure 3-8 shows the molecular structure of cyclobutane.

Naphthenes are fairly resistant to change, including oxidation, and are relatively insoluble in strong sulfuric acid. Naphthenes occur in many crude oils and may be found as a component of lubricating oil.

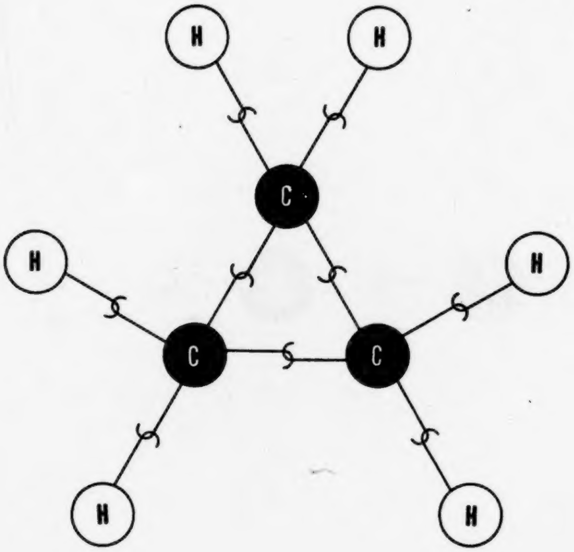

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Figure 3-7.—Molecule of cyclopropane C_3H_6—a naphthenic type of hydrocarbon.

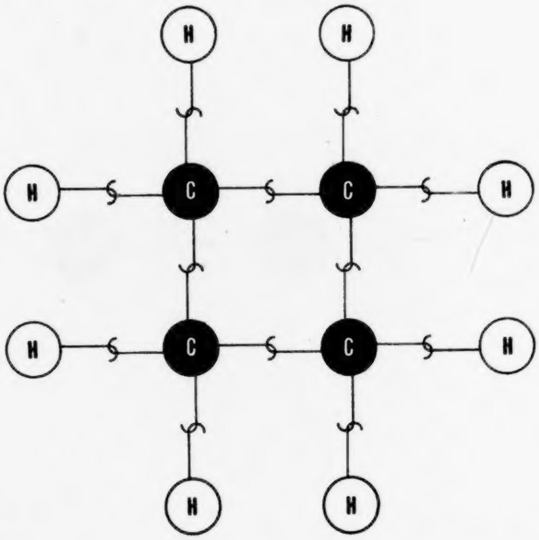

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Figure 3-8.—Molecule of cyclobutane, C_4H_8, a naphthenic type of hydrocarbon.

Olefins

The olefinic hydrocarbons are unsaturated, open-chain hydrocarbons. As in paraffinic hydrocarbons, the chain may be straight or branched. Unlike paraffins, olefins always contain one or more double bonds.

The molecular structure of ethene (ethylene), a straight-chain olefin, was shown in figure 3-4 and has been mentioned in the discussion of unsaturated hydrocarbons. Another example of a straight-chain olefin is 2-butene (butylene), C_4H_8, whose molecular structure is shown in figure 3-9.

An example of a branched-chain olefin is 2-methyl propene, (isobutylene), C_4H_8. Its structure is shown in figure 3-10.

Every olefinic hydrocarbon contains at least one double bond but may contain more than one. If two double bonds occur, the hydrocarbon is sometimes called a diolefin. Figure 3-11 shows the molecular structure of 1, 3-butadiene (erythrene), C_4H_6, which is a diolefin.

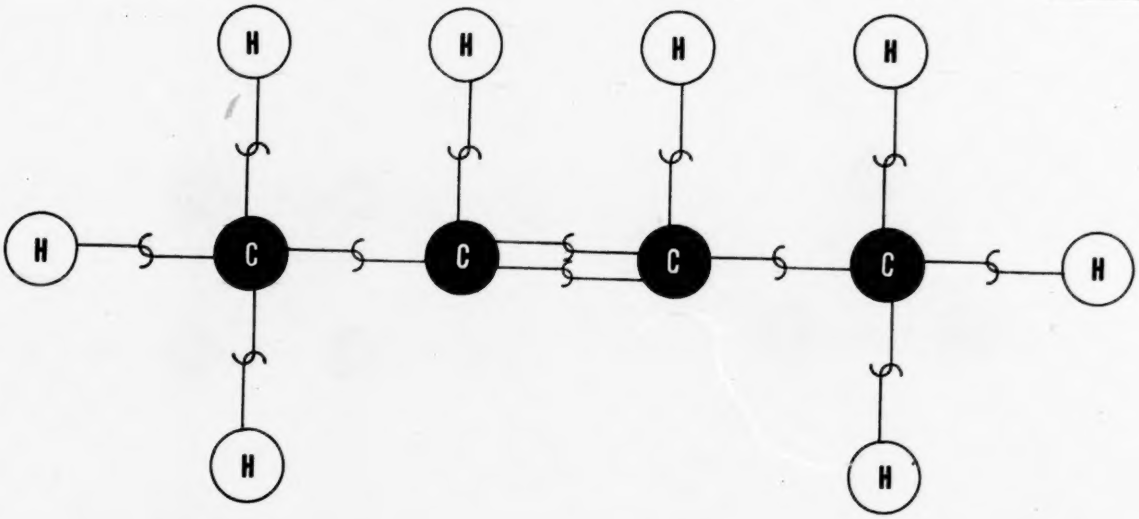
Under the Geneva system of nomenclature, a single-bonded olefin is given a name ending in ene, as ethene, butene, and hexene. A diolefin is given a name ending in diene, as propadiene. The positions of the double bonds are indicated by numbering the carbon atoms from left to right in the longest straight-chain.

Olefins are reactive hydrocarbons because of the double bond which gives them the ability to unite readily with hydrogen, or other elements such as oxygen, chlorine, and sulfur. Because of this property, high percentages of olefins are unsatisfactory for use in fuels where a high degree of stability is essential. They are, however, highly desirable in manufacturing petrochemicals. (See ch. 5.)

Aromatics

The molecular structure of aromatic hydrocarbons is characterized by at least one 6-membered ring of carbon atoms, joined together by alternate single and double bonds. The simplest aromatic is benzene (C_6H_6), sometimes called benzol. (It is not to be confused with benzine, a mixture of the lighter constituents of petroleum obtained by fractional distillation and used as a solvent.)

The benzene ring is shown in figure 3-12. The second simplest aromatic is toluene (toluol), $C_6H_5CH_3$, the principal component of TNT.



132.20

Figure 3-9.—Molecule of 2-butene (butylene), C_4H_8—a straight-chain, olefinic hydrocarbon.

Several benzene rings can join together, forming more complicated hydrocarbons. Such combinations are called polynuclear aromatics. When two benzene rings are joined together, as shown in figure 3-13, we have naphthalene. This is not to be confused with the hydrocarbon series known as naphthenes.

Any of the hydrogen atoms in an aromatic hydrocarbon—such as naphthalene—may be replaced by paraffinic, naphthenic, or olefinic compounds, or by other aromatic groups as shown in figure 3-14. Ethyl naphthalene is formed when one of the hydrogen atoms in a molecule of naphthalene is replaced by an ethyl radical (ethane minus a hydrogen atom).

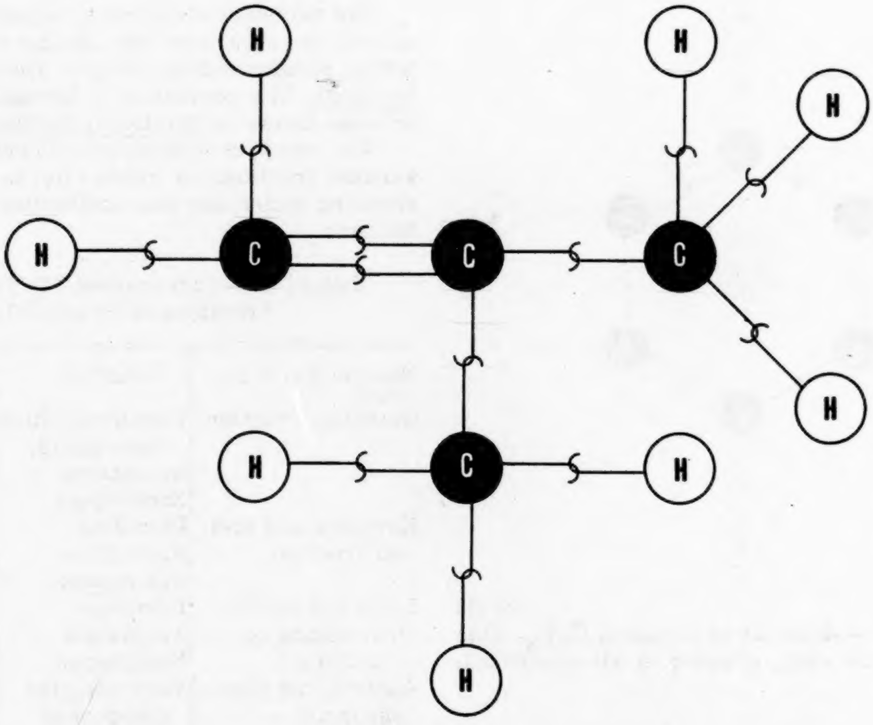
Aromatics are desirable in gasoline because they have high antiknock properties. However, they have powerful solvent tendencies and for this reason have a deleterious effect on some types of rubber. Certain aromatics are used as solvents and in chemicals such as nitrobenzene and trinitrotoluene (TNT). Many aromatics are used as intermediates in the manufacture of many dyes and synthetic drugs. Aromatic hydrocarbons are found in crude oils to some extent. They are named aromatics because most of them have a characteristic aroma.

SUMMARY OF HYDROCARBONS

In summary, the principal types of hydrocarbons found in crude oil and their structures are shown in table 3-1.

Table 3-1.—Types and Structures of Hydrocarbons

1. Paraffins	Open chain (straight or branched).	Saturated	Single bond.
2. Naphthenes	Closed chain (cyclic)	Saturated or unsaturated	Single bond. Double bond.
3. Olefins	Open chain (straight or branched).	Unsaturated	Double bond.
4. Aromatics	Closed chain (benzene ring)	Unsaturated (but in general acts like a saturated compound).	Double bond.


H
H
H
H
C
C
C
H
C
H
H
H

132.21

Figure 3-10.—Molecule of 2-methyl propene (isobutylene), C_4H_8—a branched-chain, olefinic hydrocarbon.

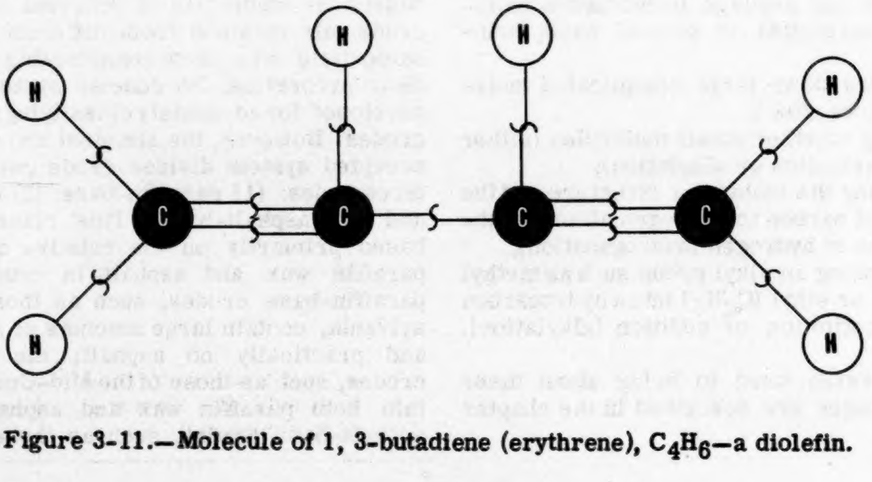


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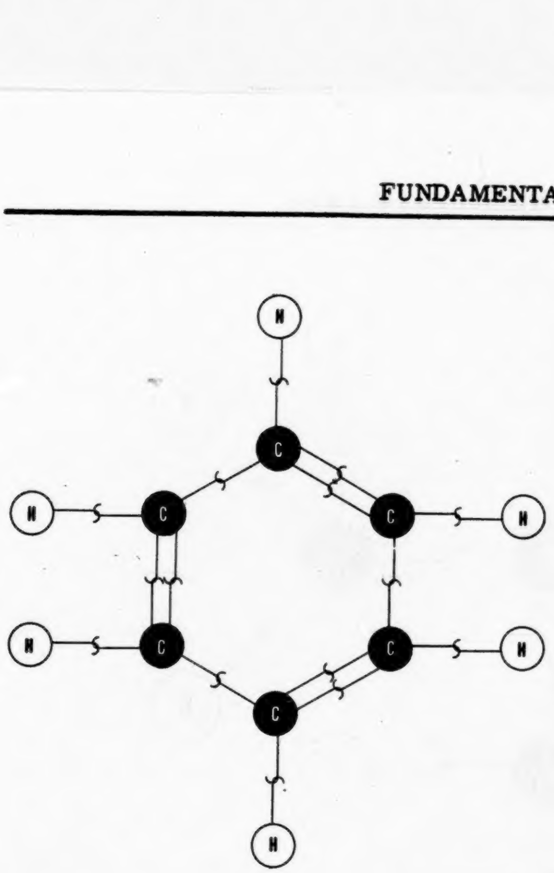
Figure 3-11.—Molecule of 1, 3-butadiene (erythrene), C_4H_6—a diolefin.



132.23
Figure 3-12.—Molecule of benzene, C_6H_6. This is the benzene ring, present in all aromatics.

The foregoing discussion of hydrocarbons has necessarily touched only upon the general types and has not discussed all the variations or possible combinations which may occur. Chemists are constantly studying these compounds, making new discoveries about them, and learning how to rearrange the molecules in order to develop more efficient petroleum products.

In the refining process, hydrocarbon molecules are rearranged in several ways, principally by:

1. Breaking down large complicated molecules (cracking);
2. Joining together small molecules (either polymerization or alkylation);
3. Changing the molecular structure and the ratio of carbon to hydrogen atoms by the addition of hydrogen (hydrogenation);
4. Introducing an alkyl group such as methyl (CH_3); or ethyl (C_2H_5) into a hydrocarbon by substitution or addition (alkylation).

The processes used to bring about these chemical changes are described in the chapter on refining.

COMPOSITION OF CRUDE OILS

The various hydrocarbon compounds in crude oil can be separated into groups of compounds having similar boiling ranges. These are called fractions. The separation is brought about by the process known as fractional distillation.

The types of hydrocarbons occurring in the various fractions of crude oils, in order of increasing molecular size and boiling point, are as follows:

Table 3-2.—Hydrocarbons Occurring in Fractions of Crude Oils

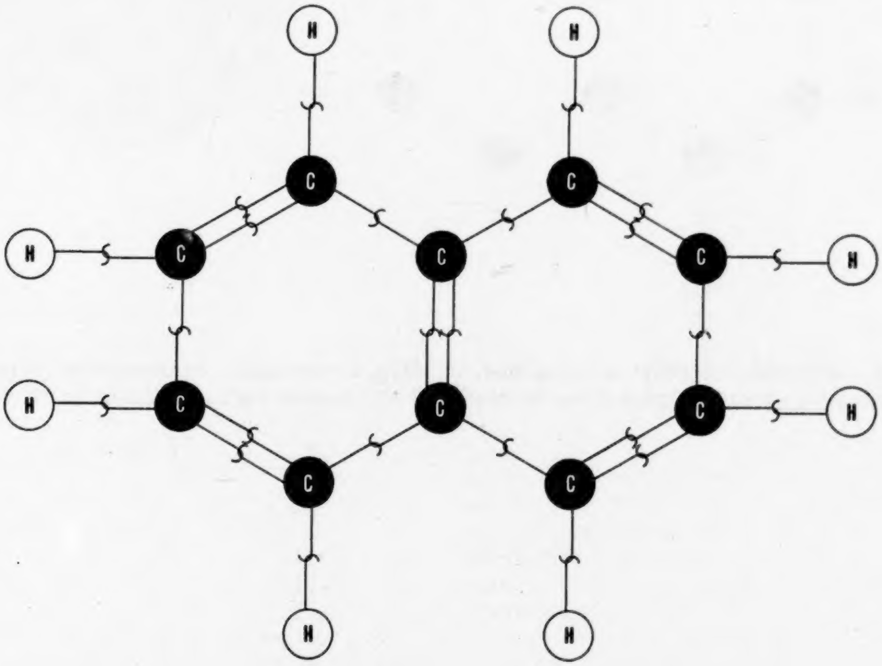
Natural gas fraction	Paraffins	C_1 to C_6
Gasoline Fraction	Paraffins (chief components) Aromatics Naphthenes	C_4 to C_{10}
Kerosine and fuel oil fraction.	Paraffins Aromatics Naphthenes	C_{10} to C_{18}
Light and heavy lubricating oil fractions.	Paraffins Aromatics Naphthenes	C_{18} to C_{45}
Asphalt (not present in all crudes).	Very complex compounds such as aromatics and napththenes.	

CLASSIFICATION OF CRUDE OILS

No two crude oils are alike. The relative amount of each component fraction and the type of hydrocarbon in any given fraction differ widely in crude oils of different origin. Even crude oils obtained from different wells in the same field may show considerable variation in their properties. No concise system has been developed for adequately classifying the different crudes. However, the simplest and most widely accepted system divides crude petroleum into three types: (1) paraffin-base; (2) mixed-base; and (3) asphalt-base. This classification is based primarily on the relative quantities of paraffin wax and asphalt in crude oil. The paraffin-base crudes, such as those of Pennsylvania, contain large amounts of paraffin wax and practically no asphalt; the mixed-base crudes, such as those of the Mid-Continent, contain both paraffin wax and asphalt; and the asphalt-base crudes, such as those of the Gulf

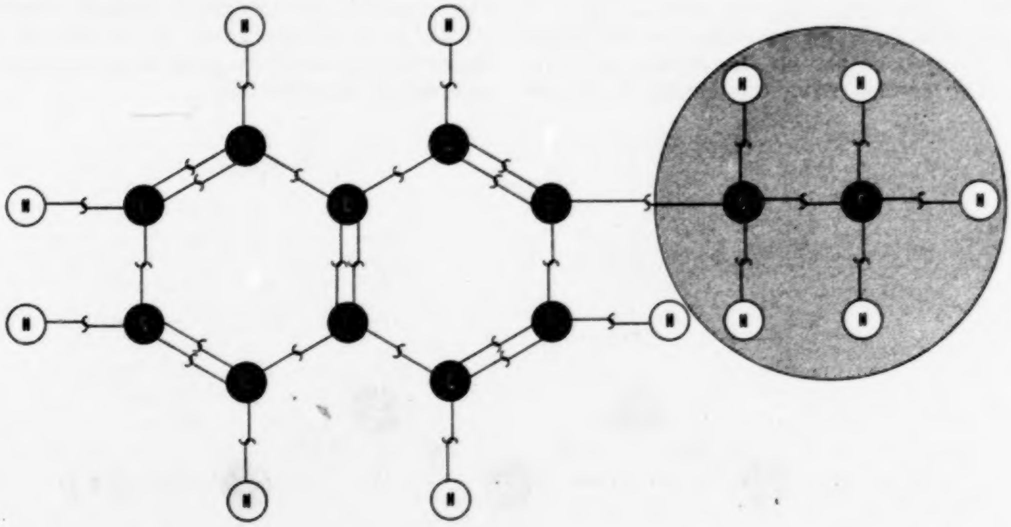
Coast and California, contain asphalt but almost no paraffin wax.

Two major sources of oil in the world are the Middle East area and the northern part of South America. In South America the crudes are of a naphthene base and similar to those of California. The crudes from the Middle East are mixed-based, somewhat on the paraffin side with a high sulfur content. A system widely used to express the quality of crude oils is based upon their specific gravity. Such a system is indicative of the general character of a crude oil so long as crudes of one of the general types listed above are under consideration.



132.24

Figure 3-13.—Molecule of naphthalene $C_{10}H_8$, a polynuclear aromatic.



132.25

Figure 3-14.—Molecule of ethyl naphthalene, $C_{12}H_{12}$, an aromatic hydrocarbon formed when one hydrogen atom of naphthalene is replaced by an ethyl radical (shown in circle).

CHAPTER 4

PETROLEUM PRODUCTION

"Petroleum production," in its most limited sense, means raising crude oil from underground geological formations to the earth's surface. In a broader sense, petroleum production also includes exploring and drilling for oil and natural gas.

Before discussing the various phases of production let us consider those fundamentals of geology which influence the formulation, migration, and accumulation of oil and natural gas.

PETROLEUM GEOLOGY

Petroleum geology is that branch of geology in which the geologist studies the nature and occurrence of rocks in the earths crust in his search for underground conditions favorable to the accumulation of oil and natural gas. One of the most useful tools of the petroleum geologist is the geologic timetable, as illustrated in figure 4-1. This provides the general background upon which the detailed search for oil must be based.

Types of Rock

The earth consists of a liquid core, a vitreous shell, and a crystalline crust. The earth's crust is composed of three main types of rocks—igneous, sedimentary, and metamorphic—which are classified according to their origin.

Igneous Rocks.—Igneous rocks, which at one time existed in a molten state, are formed as a result of cooling. Some are cooled and solidified on the earth's surface as lava. Owing to their origin and lack of porosity, igneous rocks are rarely oil-bearing.

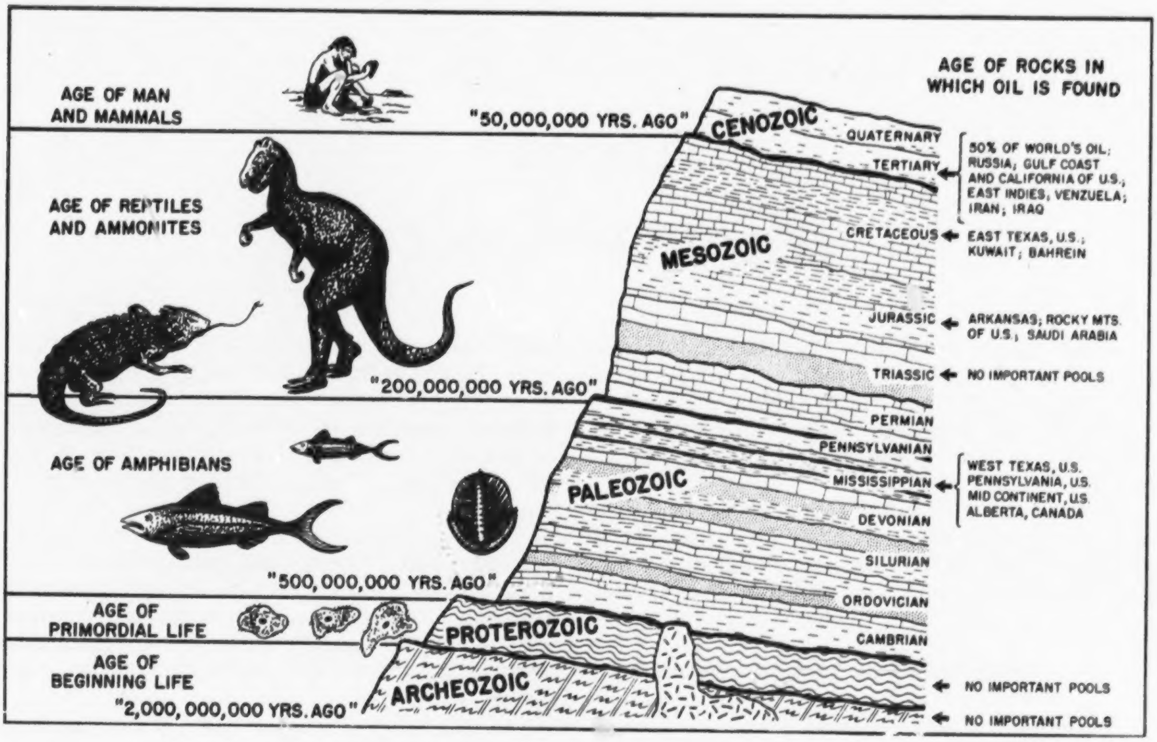
Sedimentary Rocks.—Sedimentary rocks are formed by the action of wind, water, and ice. These forces wear away rocks and soil, carry away the worn particles, and deposit them in seas, lakes, deltas, and valleys. They may also be formed from the accumulated deposition of the mineral remains of animals, from the deposits of evaporating land-locked seas, or from chemical reactions. These deposits are usually laid down evenly, forming strata of varying thicknesses as shown in figure 4-2. Typical deposits are sand, silt, clay, and calcium carbonate which, over a long period of time, are changed by the process of induration into rocks such as sandstones, shales, and limestones. Accumulations of oil occur almost entirely in sedimentary rocks.

In the largest oil field yet discovered in the United States—the East Texas Field—oil is found in sandstone; in most of the huge Middle East fields, oil is found in limestone.

Metamorphic Rocks.—When rocks of any nature are subjected to great heat or pressure—or a combination of both—their mineral composition is altered and they become known as metamorphic rocks. Slate (a modified form of clay) and marble (altered limestone) are common examples. Metamorphic rocks are valueless as potential sources of oil. Sedimentary rocks, originally suitable as oil reservoirs, are so changed by the process of metamorphism that they oil-storing capacity.

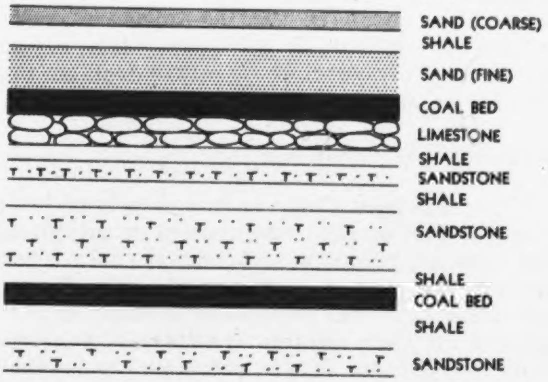
Origin of Petroleum

Most geologists believe that petroleum is the result of biochemical reactions of minute plants and animals, buried in sedimentary rocks. Temperature, pressure, and possibly other factors aid these chemical processes in changing portions of the plant and animal material into petroleum compounds. These petroleum compounds are formed as small droplets in the small pore spaces between individual grains of sand or in various types of cracks, fissures, and channels.


AGE OF MAN AND MAMMALS
"50,000,000 YRS. AGO"
AGE OF REPTILES AND AMMONITES
"200,000,000 YRS. AGO"
AGE OF AMPHIBIANS
"500,000,000 YRS. AGO"
AGE OF PRIMORDIAL LIFE
AGE OF BEGINNING LIFE
"2,000,000,000 YRS. AGO"
CENOZOIC
MESOZOIC
PALEOZOIC
PROTEROZOIC
ARCHEOZOIC
AGE OF ROCKS IN WHICH OIL IS FOUND
QUATERNARY
TERTIARY
50% OF WORLD'S OIL; RUSSIA; GULF COAST AND CALIFORNIA OF U.S.; EAST INDIES, VENZUELA; IRAN; IRAQ
CRETACEOUS
EAST TEXAS, U.S.; KUWAIT; BAHREIN
JURASSIC
ARKANSAS; ROCKY MTS. OF U.S.; SAUDI ARABIA
TRIASSIC
NO IMPORTANT POOLS
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
WEST TEXAS, U.S. PENNSYLVANIA, U.S. MID CONTINENT, U.S. ALBERTA, CANADA
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
NO IMPORTANT POOLS
NO IMPORTANT POOLS

132.26

Figure 4-1.—Generalized geologic timetable.


SAND (FINE)
SHALE
SAND (COARSE)
SHALE
SAND (FINE)
COAL BED
LIMESTONE
SHALE
SANDSTONE
SHALE
SANDSTONE
SHALE
COAL BED
SHALE
SANDSTONE

132.27

Figure 4-2.—Sedimentary deposits.

Oil Accumulations

Originally, the small particles of oil held in pore spaces between the individual grains of the formation, are scattered over a wide area. These small particles migrate as a result of physical forces. The physical forces which effect the migration and accumulation of petroleum include gas pressure and gravity. Oil and gas, being less dense than the water in the pore spaces of the formation, tend to rise to the top of the water, moving upward through the water-filled pore spaces. Then, if they can find a continuous upward route, they finally reach the earth's surface. If, on the other hand, oil and gas encounter an impervious formation which they cannot penetrate or avoid in their upward movement, migration ceases and the oil and gas will accumulate in the pore spaces of the formation underlying the impervious formation.

Oil and gas tend to concentrate in certain structural formations (reservoirs) which trap the oil. These structures may be formed by the folding, faulting, or tilting of the strata that hold or overlie the oil. Earth movements fold, bend, distort, or crush rocks in a variety of ways. The result of lateral compression is shown in figure 4-3.

Oil Structures

There are many types of structural formations favorable to the accumulation of crude oil. Among these are anticlines, salt domes, faults, and stratigraphic traps.

Anticlines.—In an anticlinal structure, the rocks comprising the crust of the earth are folded upward, as shown in figure 4-4. The oil and gas are usually found on the crest of an anticlinal structure. An impervious cap rock must be present to seal the reservoir and prevent the escape of the gas and oil into higher layers. This cap rock, in one form or another, must be present in all reservoirs to contain the oil and gas within the structure.

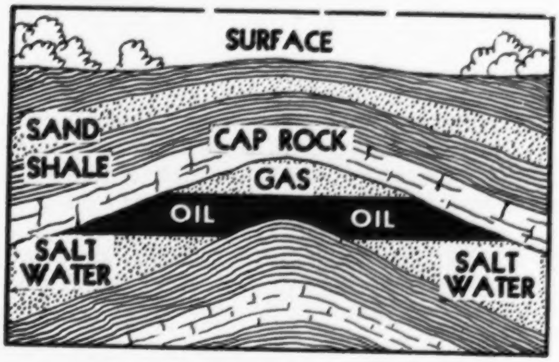


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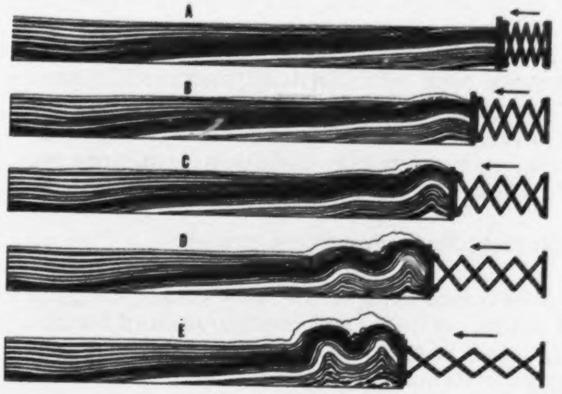
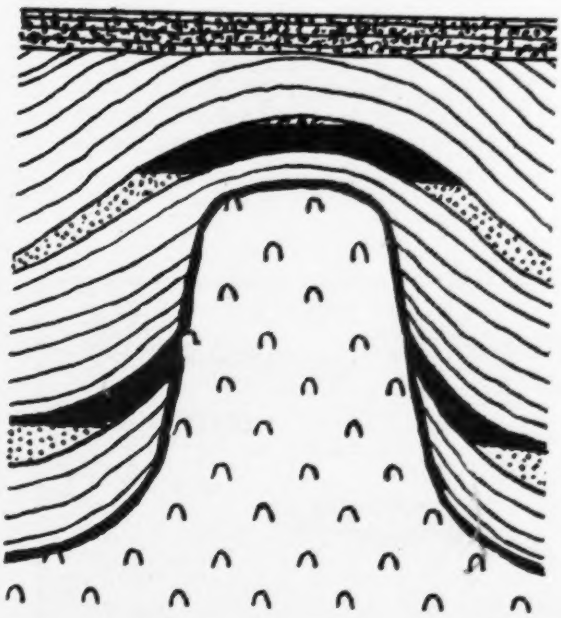
Figure 4-4.—Anticlinal structure.

Salt Domes.—The salt dome is believed to be the result of the intrusion of large masses of salt into the sediments where they are found. This salt is believed to flow as a viscous semisolid when subjected to high pressure. This intrusion creates an upward pressure and results in the doming of the overlying sedimentary rocks, as shown in figure 4-5. In this type of structure, oil accumulates within the upturned porous beds about the summit and flanks of salt core. Salt domes are found extensively in the Gulf Coast region of Texas and Louisiana.

Faults.—A fault is a structural closure caused by the fracturing of the crustal rocks



132.28
Figure 4-3.—Anticlinal folding resulting from lateral compression of earth's crust.



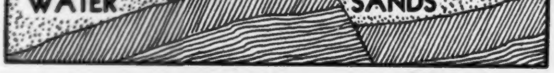
132.30X
Figure 4-5.—Salt dome.

during earth movements. In the process of folding, a reservoir for oil may be formed when a porous rock is brought into contact with an impervious layer, thus forming a trap as shown in figure 4-6.

Stratigraphic Trap.—One variety of stratigraphic trap is a formation which pinches out or disappears at its highest point and is overlaid by impervious rock. Another variety is a formation in which permeability decreases to the extent that gas and oil can no longer migrate, and therefore accumulate immediately down-dip from the "permeability pinch-out." A stratigraphic trap is shown in figure 4-7.

EXPLORATION

In most cases the search for oil is carried on scientifically by oil geologists and geophysicists. Their task is to find oil, but since only the drill can prove or disprove the existence of a petroleum deposit, the main concern of the exploration scientist is the location of areas where the existence of deposits is not improbable. As we have seen in the foregoing section, certain conditions must exist in order for an oil pool to form. First there must be source beds which contain organic matter from which the oil can be derived. Second there must be a permeable horizon, such as sandstone, through which the oil can migrate and in which it can collect. Third, there must be an impermeable barrier, so that migration cannot continue all the way to the surface.



132.31X

Figure 4-6.—Fault.

In exploring the crude oil, geologists and geophysicists employ a number of scientific methods. The most important of these are geological surveying, aerial photography, and geophysical exploration methods.

Geological Surveying (Surface)

In order to determine whether geological conditions have been favorable for the formation of oil, the geologist examines the exposed rock. He studies the type of rock and identifies its geologic age. Knowing the overall geologic history and the age of rocks in which oil is found, as shown in figure 4-1, he is able to decide whether the rocks in question are possible sources of oil.

Other indications of the presence of oil which are of significance to the geologist are asphalt, oil, or gas seepages; wax deposits; and sometimes, sulfur.

If it is determined that the geologic conditions in a region are favorable for the formation and accumulation of oil, the region is extensively studied to locate structures which might be oil reservoirs.

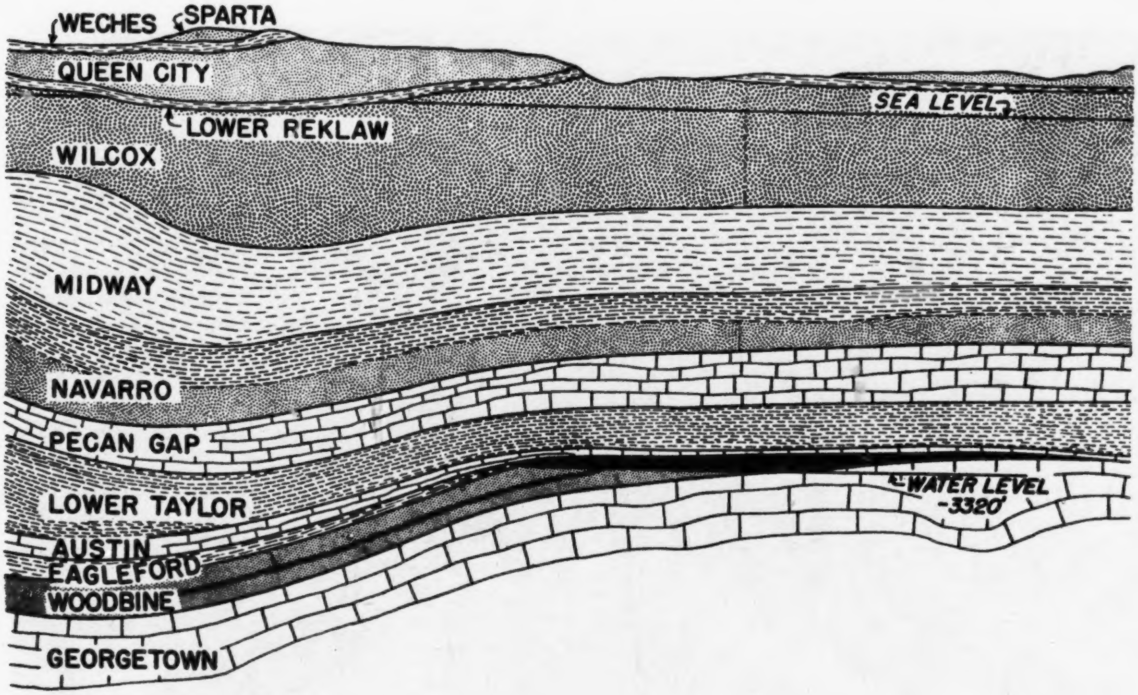
Surface indications of geologic structures exist at points where formations are exposed, such as in banks of rivers, quarries, and sides of cliffs. A scale model showing a cutaway section of an anticlinal structure is shown in figure 4-8. Measurements are made at these points to determine the inclination of the beds (dip) and also the direction in which the beds extend (strike).

The accumulation of this information from many points is plotted accurately on a map, and correlations of identical beds over a wide area are made to determine the possibility of a favorable structure for oil accumulation.

In areas where erosion of surface sediments has made rock outcrops readily accessible, surface geology is simplified. Where outcrops are not easily accessible due to covering of top sediments, an examination of shallow formations can be made by core drilling.

Geological Surveying (Subsurface)

Subsurface control; i.e. precise knowledge of the depth, attitude, and configuration of formations deep underground, is often vital to a geological analysis of petroleum possibilities. This knowledge may be obtained from the drilling logs or electrical logs of wells previously drilled for oil or gas, from deep core drilling, and occasionally from mining records.



132.32

Figure 4-7.—Stratigraphic trap.

Photographic Mapping From the Air

While direct observation of the geologic formations is best, overall physical features of a landscape often provide valuable clues to the underlying structural conditions.

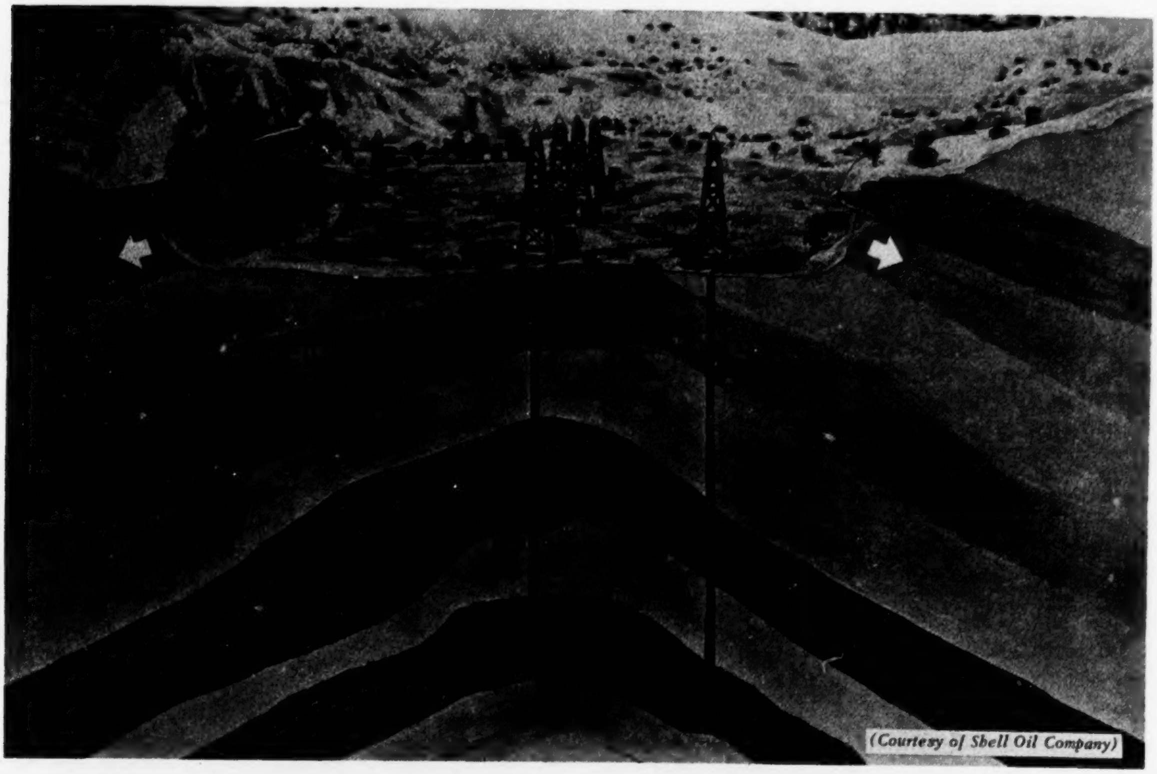
Photographic mapping is rapidly becoming one of the geologist's chief aids. Not only do photographs provide a reliable topographic base, but the use of the stereoscope in studying the photographs brings to a point of visibility a surprising amount of geological evidence, especially in densely wooded country. With the help of photographs, the geologist can see at a glance how best to arrange his traverses—the connected series of lines of constant bearing on the earth's surface, the length and bearings of which have been determined—to obtain the maximum geological data.

Geophysical Methods

Geophysical methods have largely replaced other field methods of prospecting for oil. The principal geophysical methods include the seismic, gravimetric, and magnetic methods.

Seismic Method.—The geophysical method most widely used today is the seismic method. This method of oil prospecting is based on the study of the transmission of waves caused by artificial earthquakes. The vibrations are recorded by the seismograph—an instrument originally devised to record real earthquakes.

In oil prospecting, artifical earthquakes are caused by explosives or other means. The time necessary for these shock waves to travel to a specific formation and back is recorded by the seismograph as shown in figure 4-9. The rate at which the shock waves travel varies with the character of the matter through which they travel. Soft formations are recorded weakly on film; hard formations make large jogs. Whenever two beds with different velocity characteristics are in close contact, part of the wave energy is reflected from this surface. The



(Courtesy of Shell Oil Company)

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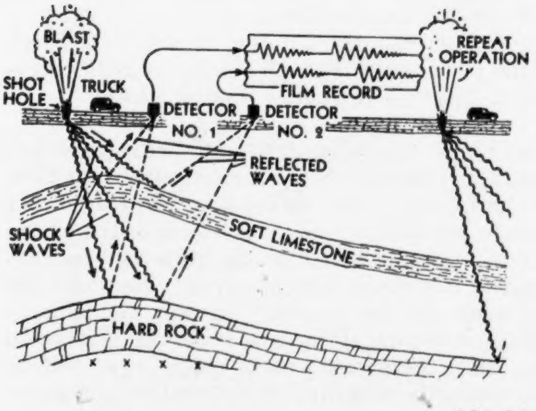
Figure 4-8.—Cutaway section of an anticlinal structure.


BLAST
REPEAT OPERATION
SHOT HOLE
TRUCK
FILM RECORD
DETECTOR NO. 1
DETECTOR NO. 2
REFLECTED WAVES
SHOCK WAVES
SOFT LIMESTONE
HARD ROCK

132.34X

Figure 4-9.—Seismograph.

depth of the layer can be determined by measuring the time taken by a wave to travel from the source of explosion at the surface, down to the reflecting layer, and back to the surface.

In seismic prospecting, the seismographic equipment is carried in specially equipped vehicles which are capable of traveling over the terrain being explored.

Gravimetric Method.—Geological structures such as salt domes, anticlines, and faults, cause slight variations in the force of gravity. Highly sensitive instruments such as the gravimeter are used to detect and measure these variations. The measurements are interpreted to show the presence of geological structures which warrant further exploration.

Magnetic Method.—In this method, a delicate instrument, called a magnetometer, is used to measure the magnetic intensity of the earth from place to place. The variations disclose magnetic anomalies which occur in the earth's surface and indicate possible structural formations. Magnetic surveys are commonly made from airplanes and afford a very rapid means of selecting the more promising localities within areas which may include many thousands of square miles. The magnetometer, however, is incapable of the more precise measurements necessary to the best selection of a drilling site. For this purpose the gravimeter or seismograph is used.

Exploratory Drilling

Geological surveying, photogrammetry and geophysical methods serve to locate geological structures which may contain petroleum. However, the actual presence of oil or gas can only be determined by drilling exploratory, or "wildcat," wells—a costly operation.

Although scientific methods are usually employed to determine where exploratory wells should be drilled, some operators still drill wells which have been located without the benefit of scientific investigation.

After various exploratory methods have been employed to determine whether favorable structures are present, or when other evidence indicates the existence of oil, one or more exploratory wells are drilled to discount positively, or prove the presence of oil. When simple anticlinal structures are present, a single well drilled near the crest of such a structure will often indicate the producing possibilities of that structure. When complex geological structures exist, such as salt domes or faults, several exploratory wells may be necessary.

If, in the drilling of a well, a structure is found to be productive, development programs are formulated for further exploration of the area and for commercial development of the field.

DRILLING

Drilling Methods

Two principal methods of oil-well drilling are employed; standard or cable tool drilling, and rotary drilling. Cable tool drilling, the older method, has been largely superseded by rotary drilling. Although rotary rigs are initially more expensive than cable tool rigs, the rotary system has enormous advantages in speed at penetration; straightness of hole; ability to control the high pressures encountered at depth, and ability to reach depths in excess of 25,000 ft, which is more than four times the practical capability of cable to tools. Cable tool usage is now confined to shallow holes and as a completion tool in productive formations which might be damaged by the pressure of the mud column used in hydraulic rotary drilling.

In the cable tool method, an oil well is drilled by the chipping action of a steel bit which is alternately raised and lowered to strike the formation. The chips mix with water or mud placed in the hole and are removed at regular intervals by a bailer.

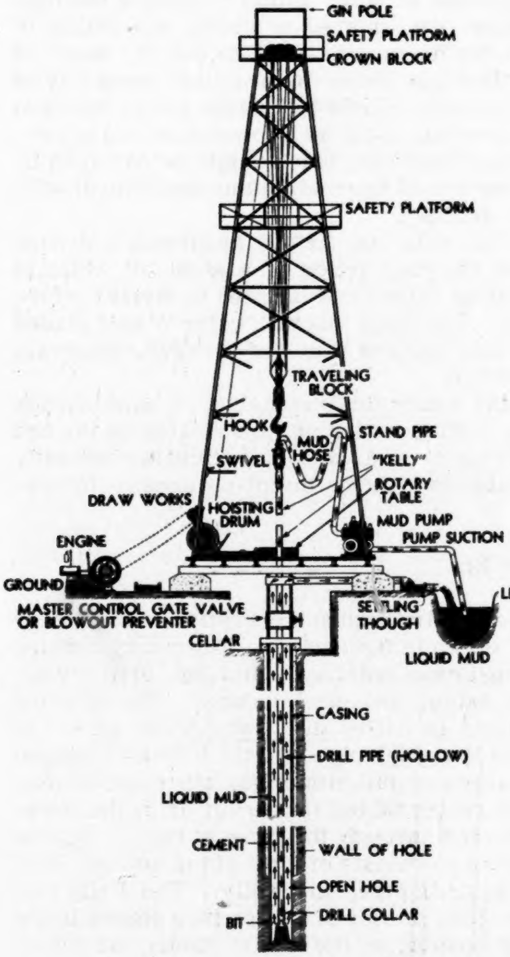
In the rotary drilling method, a hole is made by the cutting action of a bit rotated on the end of a string of pipe. Mud-laden fluid is constantly circulated to remove the cut-up pieces of formation.

Rotary Rig

The construction and operation of the rotary rig is shown in figure 4-10. The rotary drilling rig consists of hoisting equipment, drill string, rotary table, and mud pumps. The hoisting equipment is called draw works and serves to lift and lower the pipe into the hole as required for changes of dull bits or for other operations.

The rotary table is generally driven by power transmitted through the draw works. A typical drill string consists of a bit at the bottom, drill collars, drill pipe, and Kelly. The Kelly is a square joint of pipe and when it is placed in the square opening of the rotary table, the rotary table rotates the string.

The drill string is hollow, and a drilling fluid is pumped down through the inside and returned to the surface between the drill string and casing to remove the cuttings milled up by the rotation of the bit on the formation at the bottom of the hole. The swivel at the top of the Kelly allows the fluid to be pumped to the drill pipe while it is being continuously rotated. The fluid is in most cases a specially-prepared water-base mixture of barite and bentonite with various chemical additives, but it may be clear water, or compressed air or natural gas. Liquid fluids are circulated down the hole and back to the surface by heavy pumps, while circulation of air or gas is by batteries of compressors. On return to the surface, cuttings are removed by gravity, usually assisted by mechanical shakers


GIN POLE
SAFETY PLATFORM
CROWN BLOCK
SAFETY PLATFORM
TRAVELING BLOCK
HOOK
STAND PIPE
MUD HOSE
"KELLY"
SWIVEL
ROTARY TABLE
DRAW WORKS
HOISTING DRUM
MUD PUMP
PUMP SUCTION
ENGINE
GROUND
LEVEL
MASTER CONTROL GATE VALVE OR BLOWOUT PREVENTER
SETTLING THOUGH
CELLAR
LIQUID MUD
CASING
DRILL PIPE (HOLLOW)
LIQUID MUD
CEMENT
WALL OF HOLE
OPEN HOLE
DRILL COLLAR
BIT

132.35X

Figure 4-10.—Rotary drilling rig.

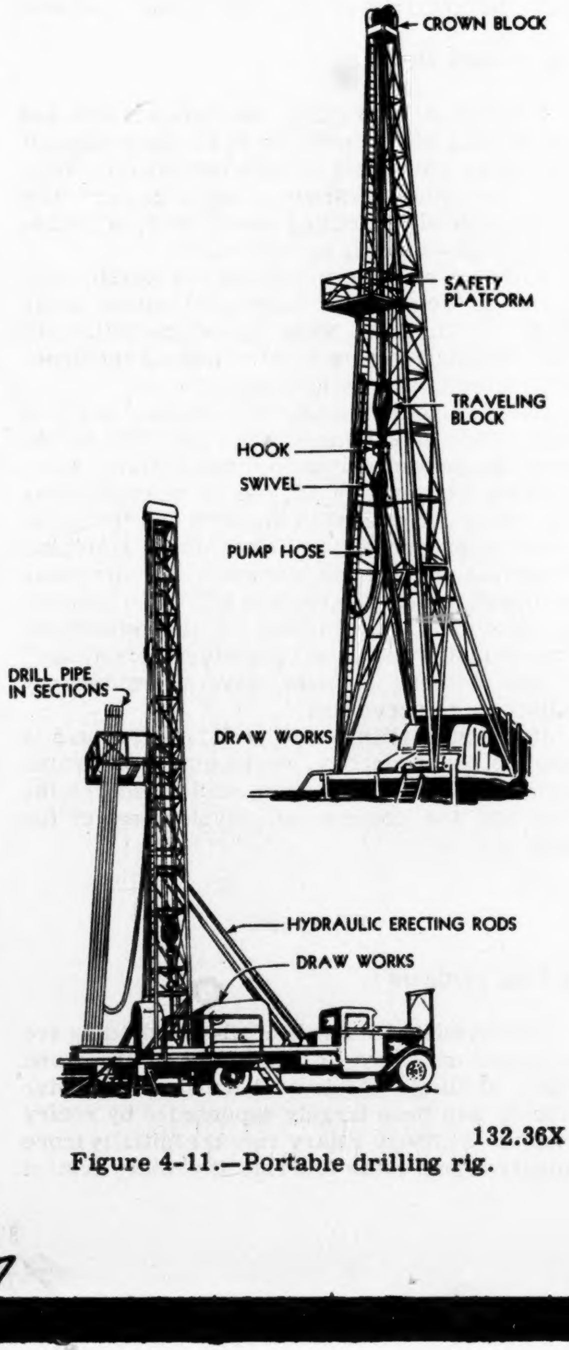
and the mud is recirculated. In the case of air and gas the cuttings fall to the ground at the point at which the air or gas is vented to the atmosphere.

At from one to five points in the drilling of a well, depending upon depth and formation characteristics, the drill string is removed and steel casing placed in the hole and cemented.

Portable Drilling Rigs

Portable drilling rigs are shown in figure 4-11. Portable rigs are becoming increasingly common in drilling operations, owing to advanced design and structure, strength and materials, transportation facilities and cost advantages.

The method employed for drilling with a portable rig is the same as that described for the rotary method. The major advantage is increased speed in rigging up and tearing down.


CROWN BLOCK
SAFETY PLATFORM
TRAVELING BLOCK
HOOK
SWIVEL
PUMP HOSE
DRILL PIPE IN SECTIONS
DRAW WORKS
HYDRAULIC ERECTING RODS
DRAW WORKS

132.36X

Figure 4-11.—Portable drilling rig.

Types of Bits

Many different types of bits have been used in rotary drilling. The two of major importance for normal drilling purposes are the drag bit, and the rock bit. These are shown in figure 4-12. In addition to these bits a diamond bit and core barrel combination are being used for drilling of certain formations.

The drag bit, when rotated, creates a slicing or chiseling action. Drag bits are used mainly in soft formations. The nozzles in a drag bit through which the drilling mud emerges from the drill string are so designed and positioned that much of the cutting action is actually an erosion of the formation by the high-velocity mud stream.

The rock bit may be of two types—the roller type or the cone type. These bits have cutters which roll on bearings. As they roll, they tend to gouge and chip the formation against which they are placed. The diamond bit has industrial diamonds set in a circular matrix which is rotated to grind up the formation being drilled. The center of the bit may be hollow and in such cases the drilled formation passes through this hole to a core barrel above the bit. When the core barrel becomes full it is removed from the well and the core removed.

Completion Methods

The primary purpose is using the methods of drilling described above is to make a hole in the ground through which the oil and gas can be recovered from the underground reservoirs. Once a production formation has been penetrated, certain operations, called completion methods, are employed. These methods have a bearing upon how efficiently and economically the oil can be produced.

The number of individual methods for completion of a well are too numerous to explain here. Therefore, two general completion methods under which all wells may be classified, are described briefly. These are the open-hole and the cased-hole method, illustrated in figure 4-13. Other methods can be used in conjunction with or in addition to the two methods mentioned.

In the open-hole method, a string of pipe is set and cemented on top of the producing formation. The formation has no protective barrier below the bottom of the pipe, and the formation is open to the well bore.

In the cased-hole method, after the hole is drilled to its total depth through the producing horizons, the casing is set and cemented, through

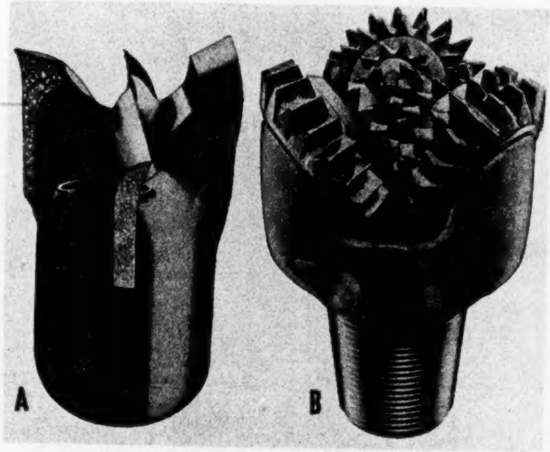


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Figure 4-12.—Types of bits: (A) drag bit, (B) rock bit.

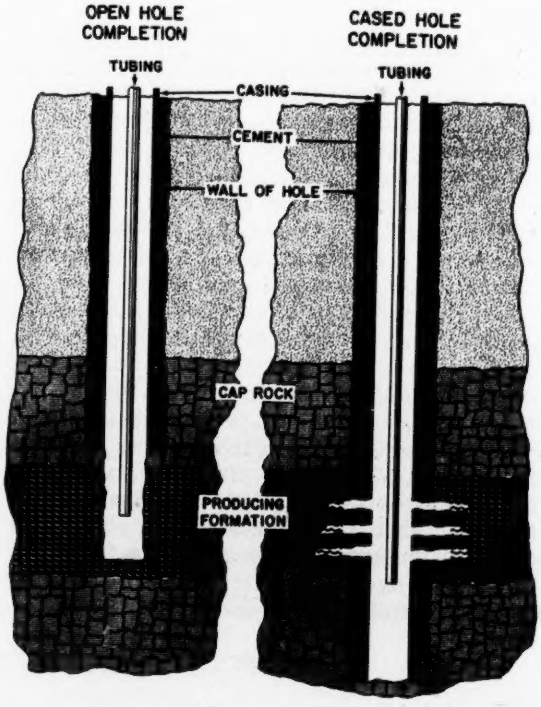

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Figure 4-13.—Open and cased holes.

the producing horizon. To produce the oil, the pipe opposite the producing formation is perforated. This may be done either before or after the pipe is placed in position. In the latter case, perforations are made by shooting projectiles through the casing in order to open channels to the formation.

There are certain standard practices which may be used to increase production when the well is first completed, or at some later stage of its life if the conditions are favorable. Two such methods are: (1) acidizing; and (2) hydrafrac.

Acidizing.—Acidizing can be used in either open-hole or cased-hole completions—primarily in limestone formations although it has been used in sandstones which have a high calcareous content. In this method, hydrochloric acid is pumped outward from the well bore, and through the pores of the formation until no acid is left in the well bore. This acid is allowed time to react and dissolve the limestone. The acid and dissolved limestone are then removed from the well, leaving larger flow channels through the formation.

Hydrofrac.—This method creates highly permeable flow channels through the formation, radiating out from the well bore. In principle, a special solution with solid material in suspension is placed at the bottom of the well. Pressure is then applied until the formation is fractured, opening channels into which the gel and sand are pumped. This is allowed to set for a certain period of time, after which the gel becomes a solution and is removed, leaving the fractures filled with highly permeable material.

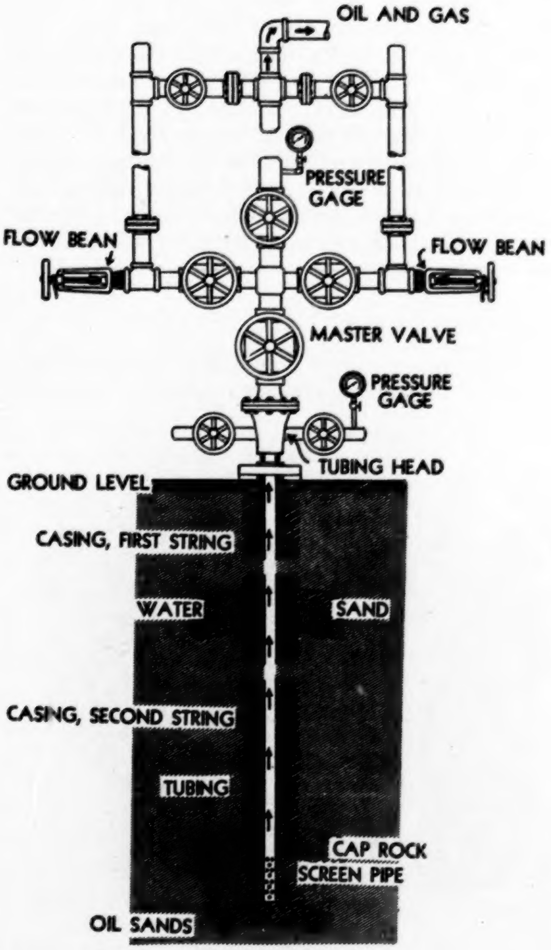
When all operations have been completed for a particular well, and the well is to be placed in production, the normal practice is to place a string of small-diameter pipe inside the casing. This pipe is called tubing and may be used as a flow channel for the oil to be lifted to the surface. After this string of pipe is placed in position, a series of valves is installed, in order that the well can be shut in or produced at a controlled rate. This series of valves, shown in figure 4-14, has been named the Christmas tree because of its complicated appearance.

PRODUCTION METHODS

Once the well has been drilled and completed in the manner dictated by experience and engineering design, it is ready to be produced—that is, the oil removed from the ground and reduced to capture in surface storage.

Primary Production

Before the oil can be lifted to the surface, it must first flow into the well bore from the surrounding formation. Natural forces existent in the reservoir formation force the oil into the well bore. These natural forces include: (1) expansion of gas mixed with or overlying the oil, (2) capillary forces exerted by water below or behind the oil, and (3) gravity drainage.



132.39X

Figure 4-14.—Christmas tree.

The first two of these forces may create sufficient pressure to force the oil to the surface. If they are too weak to do so (although still strong enough to force the oil into the well bore), the oil must be lifted to the surface artifically—either by using pumps or by the gas-lift principle. In the latter case, gas is injected either into the casing, causing the oil to flow from the tubing—or into the tubing, causing the oil to flow from the casing.

Secondary Production

Once the oil ceases to flow into the well bore by natural forces—at a rate high enough to guarantee an economic return—the well is abandoned, or secondary methods are employed. Secondary recovery methods usually employ water, gas, air, solvents, or steam to drive the oil from the formation into the well bore.

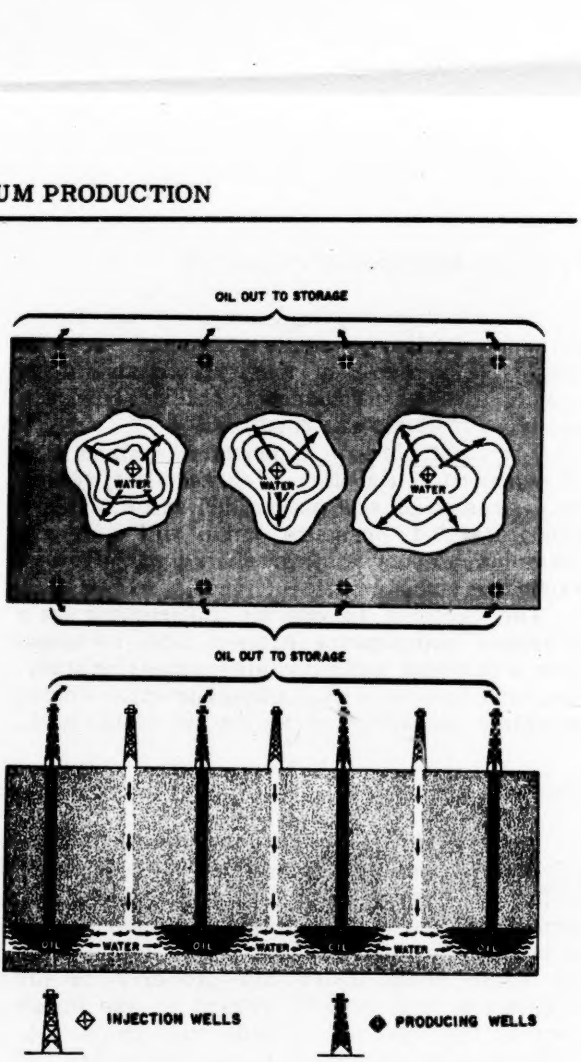
The use of water in a reservoir to produce oil after all primary methods are exhausted is called water flood or water injection. Water is injected into the formation through selected wells and oil is removed from the surrounding wells until water production of the oil-producing wells becomes excessive. Various patterns are used for location of injection and producing wells to maintain the most efficient operation. One pattern is shown in figure 4-15.

The use of air or gas for secondary recovery methods is usually termed gas drive or air drive, as the case may be. Here again, a system of injection and producing wells is employed. Production is continued until the gas-oil ratio of the producing wells becomes excessive, reaching its economic limit.

The most modern of secondary recovery methods are of a thermal nature. Heat, whether induced in the reservoir by steam injection or by controlled combustion of part of the oil in the reservoir, lowers the viscosity of the oil and facilitates its movement toward a producing well. In the case of combustion, the gases generated by combustion provide a driving force.

Once the oil has been forced into the well bore by one or more of the above-described systems, it is lifted to the surface by the same methods as those employed during the primary production period.

The process of artificially energizing reservoirs before native energy is exhausted has become common whenever engineering studies indicate that the maximum ultimate recovery of oil will thereby be obtained. Also, and although any process of artificially energizing a reservoir is casually referred to as secondary recovery, it is common to follow one secondary process with another, and sometimes a third, utilizing each until it reaches the limit of its ability to make recoverable oil which otherwise would have to be abandoned.



132.40
Figure 4-15.—A pattern for injection and producing wells.

During the past two decades, much progress has been made in designing and operating secondary recovery projects for the recovery of oil from previously depleted fields. The oil made available by secondary recovery methods has in recent years added materially, to the Nation's reserves. Many organizations such as the American Petroleum Institute, and the Pennsylvania Grade Crude Oil Association have initiated and are continuing to carry on research and experiments to increase the amount of oil recovered by these methods.

Pressure Maintenance Production

Prior to reaching the economic limit of primary production, pressure maintenance may be employed to increase the total amount of oil recovered from the reservoir before secondary recovery methods are required.

The chief purpose of pressure maintenance is explained by its title. In this method, reservoir pressures are maintained at or above a predetermined pressure which will give the maximum amount of oil production at the lowest producing cost.

The decision to operate a reservoir as a pressure maintenance project must be based upon a thorough and complete engineering study. The complexities of such studies preclude a more complete discussion of the subject in this book.

Conservation

In the early days of the oil industry, the law of capture was the rule. Oil which could be reduced to capture and put in storage tanks was considered to be the property of the person owning those tanks, regardless of whether the oil came from under his property or his neighbor's, and without regard to the injury done to the reservoir by wide-open production.

To prevent this injury to our reservoirs and to preserve this important natural resource of the nation, conservation measures have been enacted by most oil-producing states. Results of these laws have been: (1) decreased waste of natural gases separated from the oil and dispersed to the atmosphere; and (2) greater ultimate recovery of oil from reservoirs through proper and efficient use of good engineering practices.

Methods of Removing Contaminated Material

In many fields, the production of oil is associated with the production of water. Dependent upon the type of crude produced, the quantity of water produced, the amount of agitation of the mixture, and other factors, emulsions made up of oil and water may be formed. When emulsions are formed, they must be broken and the water removed from the oil prior to movement of the oil from the field to the refinery.

Where emulsions are not formed, the oil and water are separated by flowing the mixture into a tank; the water is removed from the bottom of the tank; and the oil is removed at some level above the oil-water contact. This method may also be used where emulsions are easily broken if a period of settling is allowed before removing the clean oil accumulated on top of the water. Where emulsions are hard to break, other methods, in conjunction with settling, must be used. These include chemical methods, electrical methods, and the addition of heat to the oil. Combinations of these methods—such as both the addition of heat and a chemical method—may be used, depending upon the most economical and efficient procedure as determined by engineering analysis.

Storage and Transportation of Crude Petroleum

As the crude oil comes from the ground, it is made up of both gases and liquids. Before placement in field storage tanks, the mixture is passed through a separator which separates the gas from the liquid. The gas is sold for commercial use, vented to the air and flared, or returned to the producing formation through injection wells. The liquid is placed in storage tanks until time to be moved to the refinery.

In the continental United States, the major portion of the liquid petroleum is transported by pipe line. Other methods of transportation are tank car, tank truck, and barge.

Shipment by tankers is becoming increasingly important for the importation of crude oil from foreign sources.

Upon arrival at the refinery, the crude oil is again stored until it is needed for refining.

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CHAPTER 5

PETROLEUM REFINING

Refining is essentially a manufacturing industry, using crude petroleum as its raw material to make numerous petroleum products. Refineries vary in size. For example, in the United States refineries range in processing capacity from 75 barrels per day to 365,000 barrels per day. The smallest foreign refinery has a daily capacity of 140 barrels while the largest has a capacity of 460,000 barrels per day. Refineries also vary in type. For example, some are skimming (topping) plants which turn out only one or two cuts of light distillate and residuum fuel oil; others are cracking plants, while still others are complete refineries, equipped to make a full range of products. Since crude oils vary in their yields of raw products, no two refineries employ exactly the same processes. Each is equipped to refine the available crude by the methods which produce the most profitable commercial products at the least cost.

UNITED STATES REFINERY OPERATIONS

Refinery operations in the United States between 1939 and 1963 are shown in figure 5-1.

Concentration of Refining Capacity

At the present time, 75 refineries, or 26 percent of all U.S. operating refineries, account for roughly 56 percent of all the crude oil runs to stills in this country. The largest refining company only accounts for slightly more than 9 percent of U.S. refining capacity.

Refineries are largely concentrated near major producing areas or major consuming areas. They are located throughout the producing areas of the Gulf Coast and the Middle West, the consuming areas near New York, and in the west and west coast regions. However, it was estimated at the beginning of 1964 that about half our total refining capacity is concentrated in Texas, Louisiana, and California. Refineries are most frequently located at coastal points because of the extensive use of tankers for delivering crude oil to the refineries and transporting finished products to consuming areas. The development of oil pipelines, however, has made it possible for refineries to be located near major consuming areas whether or not they are coastal.

Refineries constitute the manufacturing segment of the petroleum industry. Hundreds of thousands of wells furnish the crude oil to the relatively few refineries which process the oil into more than 2500 products which are then distributed through several hundred thousand market outlets to millions of customers. To ensure that the entire process runs smoothly and that demands for petroleum are met, oil is kept constantly on the move from the well to the consumer. Refineries operate day and night—a classic example of continuous flow operation. Careful planning is also essential to meet the daily demands of a nation that depends on petroleum for three-quarters of its energy supply, and to meet the increased demands in event of emergency.

Government and industry representatives are working together to formulate plans for safeguarding our petroleum supply network in the event of enemy attack. Experience during the last war indicated that a refinery is, in general, quite resistant to conventional bombing, because it consists of several independent units. If some units are damaged, they can be bypassed and the plant as a whole continued in operation. However, it is adjudged that the situation would be different in the event of atomic attack.

United States Crude Oil Capacity

The crude oil capacity of a refinery represents the maximum daily average crude oil

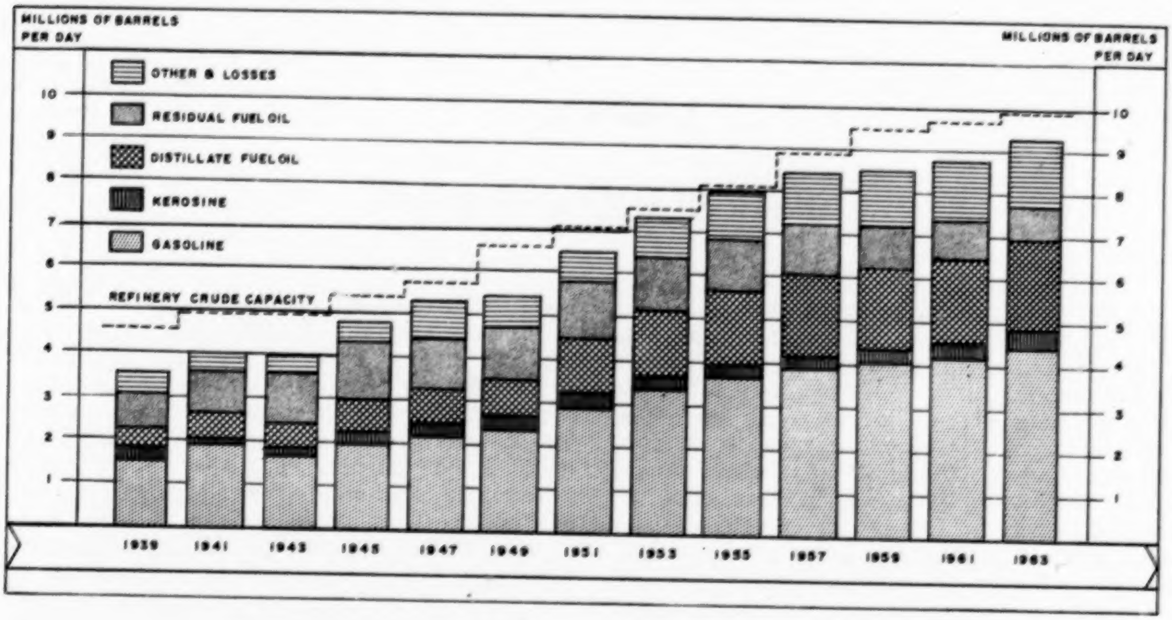

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Figure 5-1.—U. S. refinery operations between 1952 and 1963.

throughput of a plant in complete operation, with allowance for necessary shutdown time for routine maintenance, repairs, and the like. It approximates the maximum daily average crude oil run to stills that can be maintained for an extended period.

According to the Bureau of Mines annual survey of refinery capacity, there were 282 petroleum refineries operating in the United States as of 1 January 1964, with a total daily crude oil throughput capacity of 10,063,164 barrels.[1]

United States Cracked Gasoline Capacity

Cracked gasoline and reformed gasoline capacity represents the amount of gasoline that can be produced on a daily average basis under maximum sustained throughput of charging stocks of the types in current use.

The process of cracking is employed to increase the yield of gasoline per barrel of crude, to improve the quality of gasoline, and to reduce the cost per gallon of gasoline yield. Products which are catalytically cracked are generally of higher quality than those which are thermally cracked. The catalytic cracking process was introduced commercially in 1937 and is being increasingly used in the manufacture of gasoline. Because this process is essential in the production of high-quality motor and aviation gasolines today, the capacity of the United States to produce this product is an important logistic consideration.

Product Availability

In any barrel of crude, the sum of the parts equals the whole. Thus, if the yield of any fraction is increased, it must be at the expense of another fraction as illustrated in figure 5-2. For example, jet fuel and kerosine are made from similar fractions. Thus, overall programming is required to ensure that one of these products is not produced at the expense of the other. Overall planning is also necessary in times of national emergency to meet essential civilian as well as military requirements. One of the major problems in World War II was meeting military requirements for high grade aviation gasoline. As

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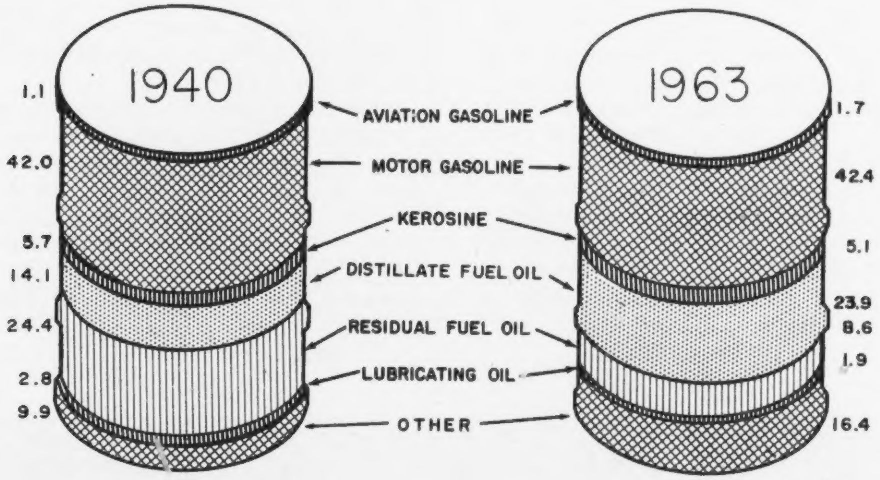
[1] U.S. Bureau of Mines, "Petroleum Refineries in the United States, January 1, 1964".



132.42

Figure 5-2.—Comparison of available liquid petroleum products, by percent, in 1940 and 1963.

a result, the production of motor gasoline was curtailed and civilian gasoline rationing instituted. While wartime changes in refinery yields result in sacrifice on the part of civilian consumers, this ability to change the yield of a barrel of crude is a distinct advantage in planning and meeting requirements.

The problem of availability has affected the development of jet fuel, particularly JP-1, the first jet fuel developed for United States military use. JP-1 was abandoned because its availability was considered to be only 3 percent of the average barrel of crude. JP-3 was then developed. Its potential availability is considered to be 60 percent of the average barrel of crude petroleum. There were, however, objections to the performance of this fuel, and subsequently JP-4 was developed to overcome the performance disadvantage of JP-3 and yet meet availability requirements. While the vapor pressure limitation on JP-4 lowers its availability to some extent, its potential availability is considered to be approximately 35-45 percent of the average barrel of crude petroleum. JP-5 was then developed to provide a fuel that is relatively safe for storage and use aboard aircraft carriers and other ships. The high flash point and low freeze point requirements for JP-5 fuel restricts its availability and eliminates the use of certain crudes. Recent developments in refinery processing methods have greatly improved the availability of JP-5 fuel. Its potential availability is considered to be approximately 6 percent of the average barrel of crude. JP-5 is the Navy's primary jet fuel.

Petroleum Technology

Technological advances in petroleum refining have yielded products of improved quality and increased quantity. Such advances mean a more efficient utilization of our crude oil reserves since products of an enhanced economic worth are obtained from crude oil fractions of less value.

Today, the petroleum industry is producing enormous volumes of specialized products, not only for motor and aviation fuel use, lubricants, heating oils, fuels for industrial use, and many others, but also for use by those industries requiring organic chemicals that can be produced from petroleum. Today, more than 68 percent of all synthetic organic chemicals manufactured in the U.S. is derived from petroleum raw materials. Petrochemicals account for 35 percent of chemical production and 70 percent of the production value of all chemicals. Yet to produce the large quantities of petrochemicals only requires 4 percent of the crude oil and natural gas produced in this country.

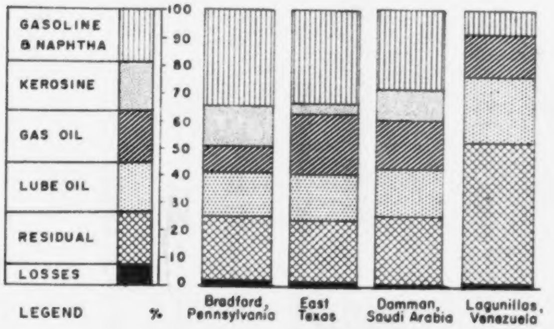
According to the American Petroleum Institute, a representative refinery, with a capacity of 100,000 barrels a day, costs 125 million dollars. Some refineries are much larger than this, capable of refining 365,000 barrels a day, while others are small plants, refining as little as 75 barrels a day. (View of a modern refinery is shown in fig. 5-3.)

Crude oils vary in their yields of raw products because of the differences in the relative amount of each component fraction and in the type of hydrocarbon in any given fraction. (The difference in the raw products yield of several types of crude is shown in fig. 5-4.) Consequently, no two refineries employ exactly the same processes, but each employs only those processes which will produce from the available crude the most profitable commercial products at the least cost.

Although many different processes are used in refining, only the major ones are discussed here. An overview of refinery operations is shown in figure 5-5, which traces crude oil from the well to the finished products. The major processes, which may be subdivided as: (1) separation processes, and (2) conversion processes, are summarized in the following two sections.

132.43

Figure 5-3.—View of a modern refinery.



132.44

Figure 5-4.—Comparison of various types of crude oil with respect to raw products yield.

SEPARATION PROCESSES

Separation processes are physical processes employed to segregate the hydrocarbons in crude oil according to either boiling range, or hydrocarbon types. The process of fractional distillation is used to separate hydrocarbons into groups having similar boiling ranges. Absorption is used to extract hydrocarbons from gases. Solvent extraction is employed to separate hydrocarbons according to type. These separation processes are described in the following sections, with emphasis on distillation because it is employed in all cases as the first step in refining. Absorption and solvent refining are secondary steps which may or may not be applied, depending on the end product desired.

Fractional Distillation

As explained in chapter 3, crude petroleum is a mixture of many complex hydrocarbons, all of which have different boiling points. By the process of distillation, the various hydrocarbon compounds in crude oil can be separated, physically, into groups of hydrocarbons (fractions or cuts) having similar boiling ranges. The boiling ranges are shown in figure 5-6. (It should be noted that since each fraction has a boiling range, rather than a boiling point overlapping occurs.) Because of the difference in boiling ranges, different fractions are vaporized at different temperatures. The process of distillation includes: (1) heating the crude oil to form vapors, and (2) condensing the vapors to liquids.

To effect the separations required in modern petroleum refining, not one but many distillations are necessary. These distillations are carried out as a continuing process in which a stream of heated crude oil is continuously charged to a fractionating tower and the vapors and bottoms continuously withdrawn.

The first distillation usually takes place at atmospheric pressure. In this process, the light ends (fraction having the lowest boiling point) are drawn off. This process is frequently referred to as stripping because the crude is stripped of its more volatile components. It is also called topping or reducing. The residue, known as topped crude or reduced crude is then ready for further processing.

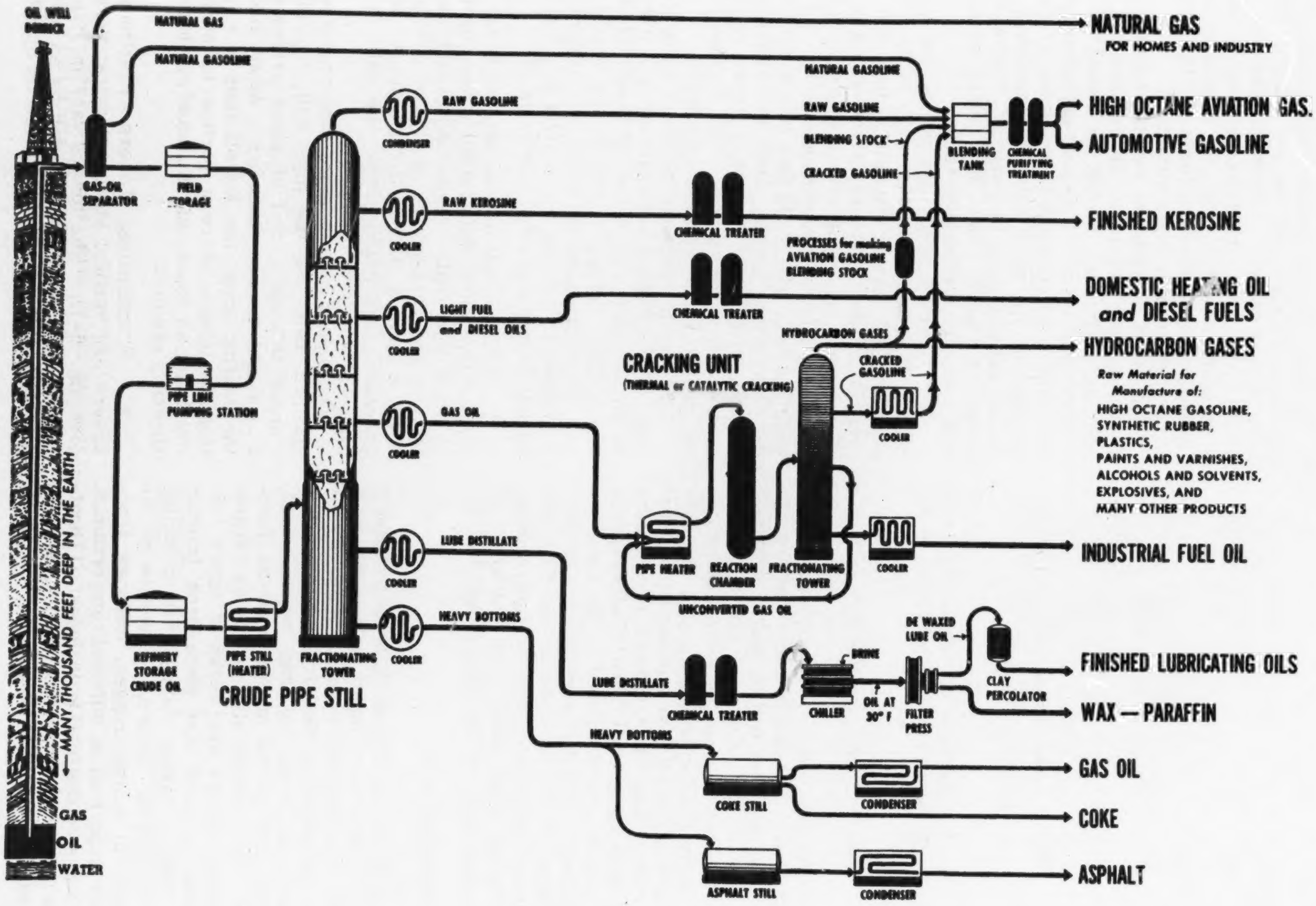
The topped crude, stripped of its lower boiling fractions, requires much higher temperatures for further separation than does the original crude. However, extreme temperatures cause cracking (decomposition) which adversely affects products manufactured from topped crude. To avoid this cracking, but at the same time to bring about the desired separation, distillation of topped crude is often carried out under vacuum. The residue from the vacuum still is known as residuum.

The major equipment required for the process of distillation consists of: (1) stills in which the charge is heated; (2) towers in which the various boiling fractions are separated; and (3) condensers in which the vapors are converted to liquids. The first two types of equipment are described briefly below.

1. Stills.—Crude distillation may be accomplished in a shell still, which is now obsolete, or in a pipe still. When using shell stills, the oil was charged into a closed cylindrical shell or into a series of such shells. Heat, generated in a firebox under the still, is applied to the outside of the still.

The pipe still is a more modern and more efficient unit. In the pipe still, the oil is pumped through a coil of pipes arranged in a suitable heating chamber. After leaving the heating zone, the hot oil runs to a fractionating tower where a portion is taken off overhead, as vapor, and the liquid portion continuously removed.

2. Fractionating Towers.—Fractionating towers are vertical steel cylindrical vessels. (See fig. 5-7.) The towers vary in size depending upon their use but may be as high as 100 feet, and as wide as 25 feet in diameter.


OIL WELL DERRICK
NATURAL GAS
NATURAL GASOLINE
GAS-OIL SEPARATOR
FIELD STORAGE
PIPE LINE PUMPING STATION
REFINERY STORAGE CRUDE OIL
PIPE STILL (HEATER)
FRACTIONATING TOWER
CRUDE PIPE STILL
MANY THOUSAND FEET DEEP IN THE EARTH
GAS
OIL
WATER
CONDENSER
RAW GASOLINE
COOLER
RAW KEROSINE
LIGHT FUEL and DIESEL OILS
GAS OIL
LUBE DISTILLATE
HEAVY BOTTOMS
CHEMICAL TREATER
CHEMICAL TREATER
CRACKING UNIT
(THERMAL or CATALYTIC CRACKING)
PIPE HEATER
REACTION CHAMBER
FRACTIONATING TOWER
UNCONVERTED GAS OIL
HYDROCARBON GASES
CRACKED GASOLINE
COOLER
COOLER
PROCESSES for making AVIATION GASOLINE BLENDING STOCK
NATURAL GASOLINE
RAW GASOLINE
BLENDING STOCK
CRACKED GASOLINE
BLENDING TANK
CHEMICAL PURIFYING TREATMENT
LUBE DISTILLATE
CHEMICAL TREATER
BRINE
CHILLER
OIL AT 30° F
FILTER PRESS
DE WAXED LUBE OIL
CLAY PERCOLATOR
HEAVY BOTTOMS
COKE STILL
CONDENSER
ASPHALT STILL
CONDENSER
NATURAL GAS
FOR HOMES AND INDUSTRY
HIGH OCTANE AVIATION GAS.
AUTOMOTIVE GASOLINE
FINISHED KEROSINE
DOMESTIC HEATING OIL and DIESEL FUELS
HYDROCARBON GASES
Raw Material for Manufacture of:
HIGH OCTANE GASOLINE,
SYNTHETIC RUBBER,
PLASTICS,
PAINTS AND VARNISHES,
ALCOHOLS AND SOLVENTS,
EXPLOSIVES, AND
MANY OTHER PRODUCTS
INDUSTRIAL FUEL OIL
FINISHED LUBRICATING OILS
WAX — PARAFFIN
GAS OIL
COKE
ASPHALT

81.71X

Figure 5-5.—Flow chart tracing crude oil from well to finished products.

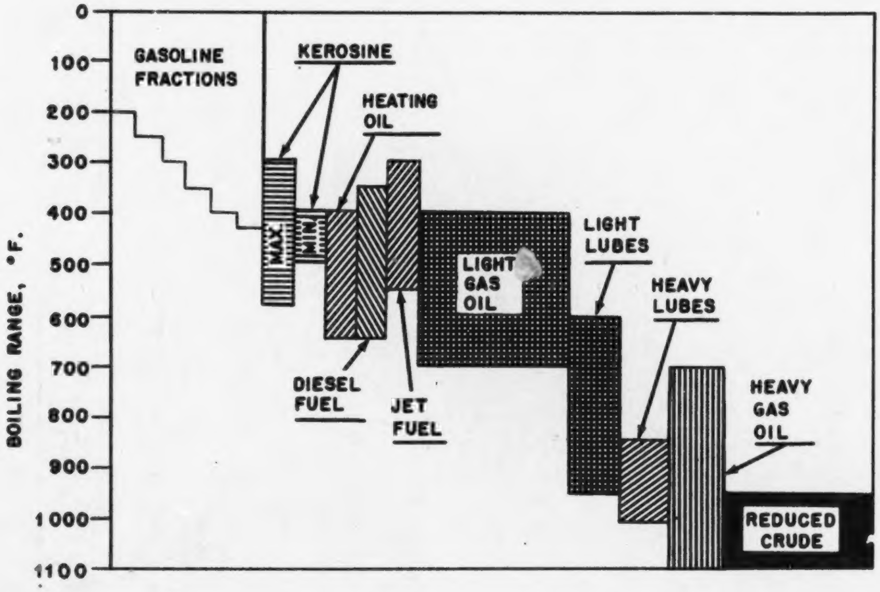


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Figure 5-6.—Boiling range of fractions.

Bubble cap-type fractionating towers contain varying numbers of trays, the number of trays depending upon the separations desired. Each tray is perforated by many holes, each hole having a lip several inches high. (See fig. 5-8.) An inverted steel cap (bubble cap) fits loosely over each hole and extends beneath the surface of liquid condensed on the trays. A downflow pipe extends from each tray to the tray below. Through this pipe, excess liquid works its way down through the towers. This liquid, known as reflux, serves to condense the vapors. (To condense vapors, latent heat which made them vapors must be removed. When the vapors are mixed with the liquid, the liquid takes up the latent heat which, in turn, causes evaporation of some of the liquid.)

Heated oil from the pipe stills enters the tower near its base and, vaporizing, passes up through the holes of the tray directly above. As the vapors rise in the bubble caps, they are forced back into the liquid on the tray. Bubbling through the liquid on the tray, some of the vapors condense and are drawn off at the side. Uncondensed vapors rise to succeeding trays where the condensation and evaporation cycle is repeated. Gasoline, a light fraction, is the first to turn into a vapor and the last to recondense. Therefore, it rises to the top of the tower as a vapor and is removed. (This fraction is known as straight-run gasoline.) The other fractions are withdrawn from trays lower in the tower as they condense, the fraction with the highest boiling point being drawn off at the bottom of the tower. (The order in which the various fractions condense is shown in fig. 5-5.)

Bubble cap trays are only one type of tower packing. There are several alternate devices used. Bubble cap trays are common and are used here as a typical case.

Absorption

In refining crude oil, hydrocarbon gases are formed. These gases may be sold for consumption or used as fuel in the refinery. However, they contain certain hydrocarbons (primarily butane and pentane) which are desirable for the manufacture of gasoline and other products. These hydrocarbons are removed from the gases by absorbing them in an oil with a high affinity for the light hydrocarbons. Mineral seal oil, which has a slightly higher boiling range than kerosine, has been

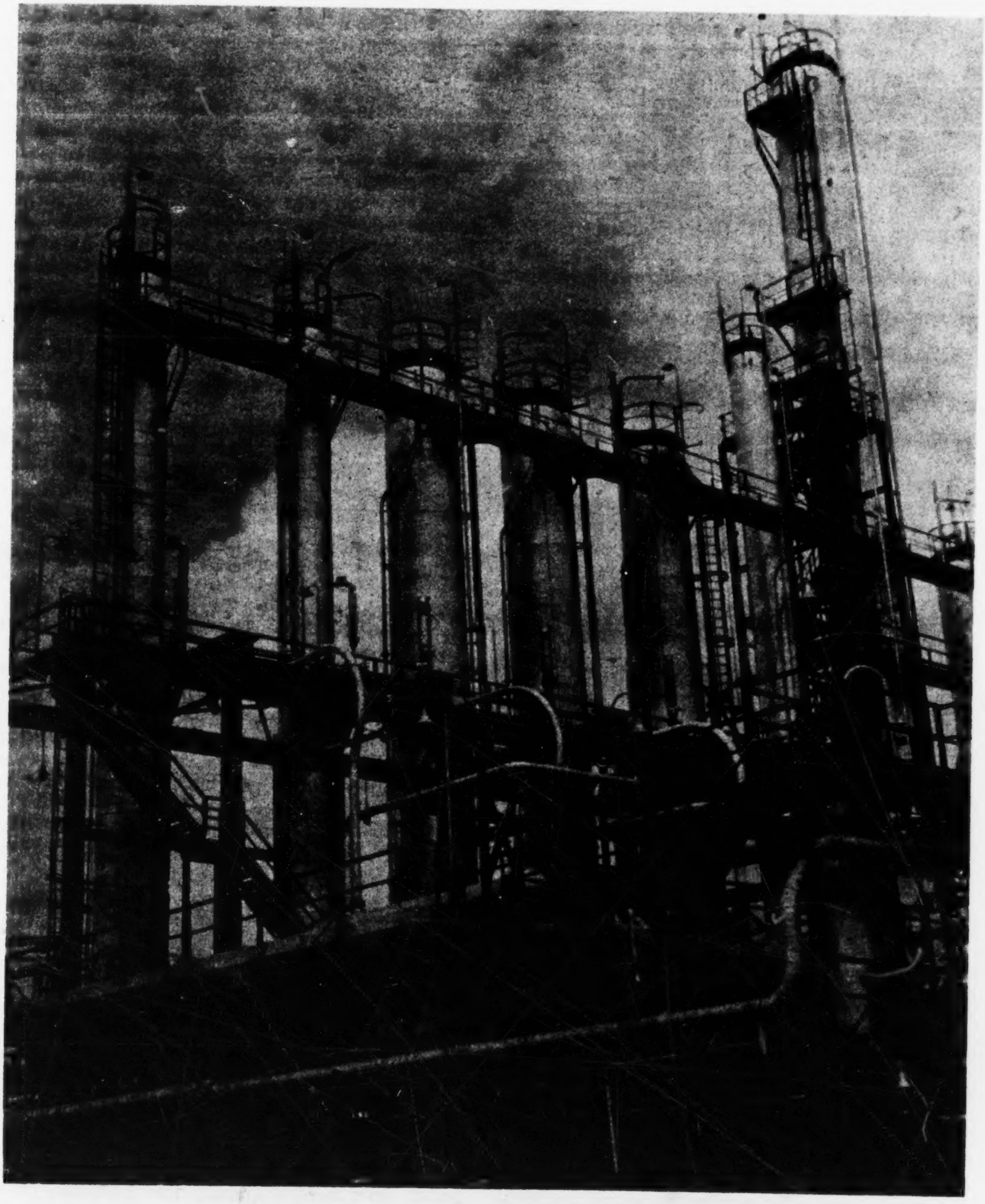

Figure 5-7.—Fractionating towers in a modern refinery.

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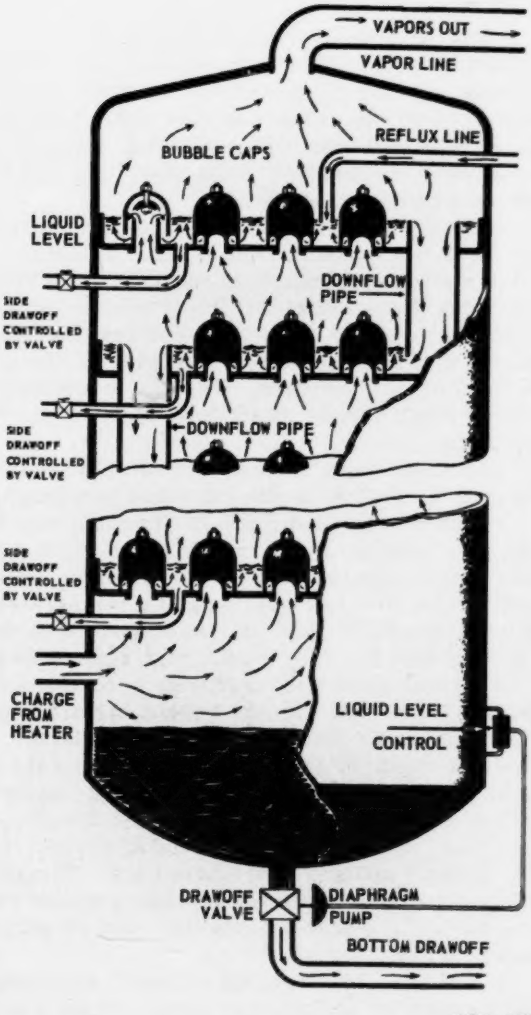


132.48X

Figure 5-8.—Bubble trays.

widely used in the past, but more recent practice employs an even lighter oil such as kerosine. (The closer an oil is to the weight of the hydrocarbons it is absorbing, the better its absorption qualities. However, if it is too close, subsequent separation becomes difficult.)

In the absorption process, the mixture of gases is pumped into the bottom of an absorption tower. Absorption oil is simultaneously passed in at the top of the tower. As the gases ascend, the absorption oil descends over and through the tower packing, absorbing the higher boiling fractions from the gas. The absorption oil carrying the absorbed hydrocarbons passes out at the bottom of the unit and then to a fractionating tower where separation of the absorbed material from the absorption oil takes place. The oil goes in a continuous cycle and returns to the absorption tower. The absorbed material, now separated from the oil, and designated as absorption plant naphtha, is sent to other towers for further fractionation.

Solvent Extraction

Each boiling point fraction, separated by fractional distillation of crude oil, contains various types of hydrocarbon molecules. In order to separate the types of compounds or to extract compounds desired for other uses, a third component (solvent) is frequently employed. This process is used in refining lubricating oils, and in refining other oils for specialized purposes. Extraction is also used for separating specific compounds such as benzene, toluene and xylene from complex mixtures.

By this physical process the mixture is separated into two fractions. That portion of the oil which remains undissolved and is not removed by the selective solvent is called raffinate. The material removed with the solvent (and later separated) is called extract. Many different solvents are employed in the petroleum industry, the choice of the specific solvent depending upon the compounds to be extracted.

CONVERSION PROCESSES

Most of the components separated by the distillation of crude oil must undergo certain conversion processes before they become marketable products. In the conversion processes, the ratio of carbon to hydrogen is changed and the size and arrangement of the hydrocarbon molecules are altered. Desired conversion may be accomplished by employing one or more processes such as: (1) cracking; (2) polymerization; (3) alkylation; (4) hydrogenation; (5) dehydrogenation; (6) isomerization; (7) reforming; and (8) combination processes which involve reforming and hydrogenation. These processes are described briefly in the following pages.

Cracking

Cracking is the process of subdividing large hydrocarbon molecules into smaller ones. When molecules are heated, the effect is to weaken the grasp that one atom has on another. If the temperature is sufficiently high and is maintained in that condition long enough, it is possible to break some of the mutual bonds between the carbon atoms. This results in the breaking up or cracking of the original molecule into two or more smaller molecules. A simple cracking reaction is that of propane (C_3H_8) cracking into ethylene (C_2H_4) and methane (CH_4). A more complicated equation is the basic reaction occurring in a cracking plant where gas oil with an average molecular weight equivalent to $(C_{13}H_{28})_2$ is cracked to methane (CH_4), butylene (C_4H_8), coke (2C), dodecane ($C_{12}H_{26}$), heptane (C_7H_{16}), and hydrogen (2H).

Commercially, the purpose of cracking is to increase the yield of gasoline per barrel of crude by subdividing large hydrocarbon molecules to form the lighter hydrocarbon components of gasoline, and to improve the quality of gasoline.

Cracking is accomplished by means of heat. The rate and severity of cracking is a direct function of the temperature to which the oil is raised by application of heat and the time allowed for the reaction. The reaction may be accelerated by the use of a catalyst. Pressure is used in cracking units to confine the volume of oil and vapors to manageable size. Pressure does not accomplish cracking, in fact, it has a slight tendency to suppress cracking and a definite tendency to promote polymerization (the opposite of cracking) of the products of the cracking reaction. By careful control of the temperature at which the cracking reaction is carried out, the maximum of desirable constituents can be produced. Extremes of temperature and time would convert any oil to light gases and coke.

A cracking process using only temperature and time is called Thermal Cracking. When a catalyst is added, the process is called Catalytic Cracking. A catalyst is a substance which will influence a chemical reaction without being changed itself.

Two types of charging stock are processed in cracking units. Type I is a residual material which in itself may vary within wide extremes from a topped crude (a crude oil from which only gasoline has been removed) to a heavy residuum which may be the residue of a crude oil after having been stripped under vacuum.

Type 2 is gas oil which has been distilled from crude oil. The term gas oil also covers a wide variety of materials ranging from a light cut of oil little heavier than kerosine to a wide cut gas oil containing everything in crude oil heavier than gasoline, except the very heavy residuum.

Although some refiners charge topped crude to catalytic cracking units, this practice is not widespread because of the high coke yield from the heavy part of the crude which accumulates on the catalyst reducing its efficiency and creating other problems in the operation of the process. Gas oil is the more conventional charge stock for catalytic cracking units.

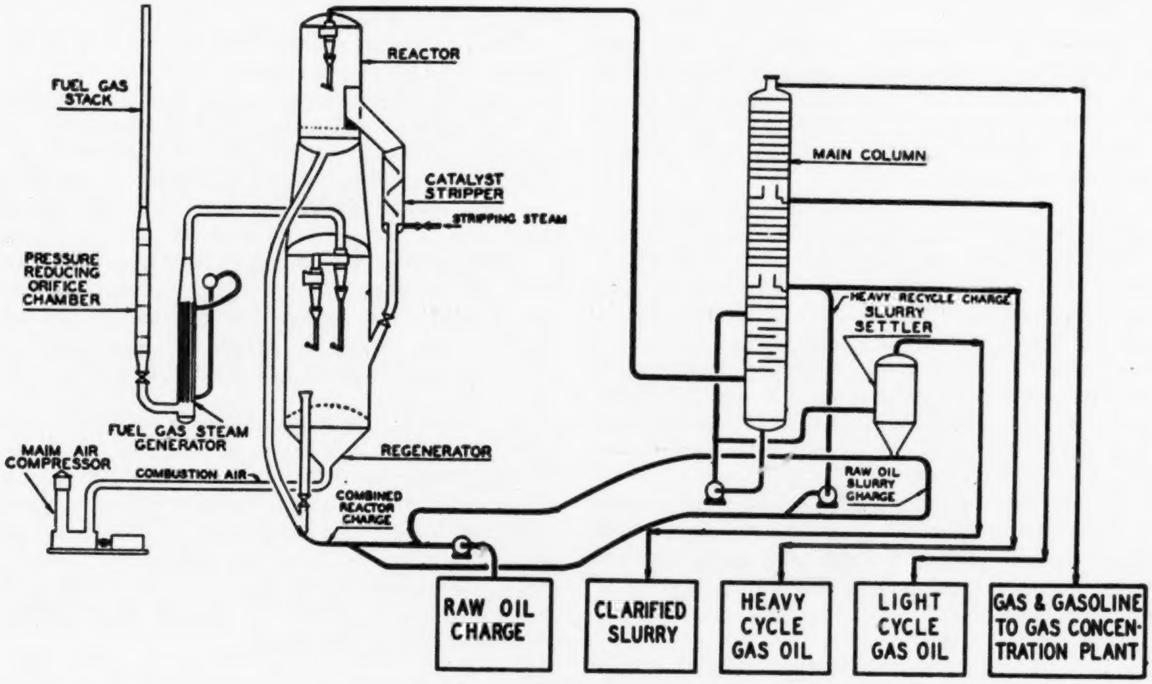
The methods of thermal and catalytic cracking are described in the following paragraphs:

1. Thermal Cracking.—In thermal cracking, the charge stock is subjected to intense heat and pressure for a period of time. Normally, this process operates at a temperature of approximately 900° F and under a pressure of 200 to 750 pounds per square inch.

Thermal cracking produces a mixture of hydrocarbons that closely resembles crude oil with respect to boiling range. The mixture is distilled right in the cracking unit, and those parts of the mixture which are not desired for finished products are returned to the cracking zone so that the net products are: (1) dry gases (methane and ethane) and (2) liquefiable petroleum gases (essentially propane and propylene), (3) cracked gasoline, and (4) either heavy fuel oil or coke.

2. Catalytic Cracking.—There are three main types of catalytic cracking: (a) the static or fixed bed process; (b) the moving bed process; and (c) the fluid process. The fluid process is most widely used and a diagram of this process is shown in figure 5-9.

In the fluid catalytic cracking process, a fine sand-like porous material is used as the catalyst. As cracking takes place carbon is deposited on the surface of the catalyst. This carbon is burned off after which the catalyst can be used again and again. The removal of carbon from the catalyst is known as regeneration. The catalyst flows continuously between the two process stages of reaction and regeneration, propelled by gases. Because the


FUEL GAS STACK
REACTOR
MAIN COLUMN
CATALYST STRIPPER
STRIPPING STEAM
PRESSURE REDUCING ORIFICE CHAMBER
HEAVY RECYCLE CHARGE
SLURRY SETTLER
FUEL GAS STEAM GENERATOR
MAIM AIR COMPRESSOR
REGENERATOR
COMBUSTION AIR
RAW OIL SLURRY GHARGE
COMBINED REACTOR CHARGE
RAW OIL CHARGE
CLARIFIED SLURRY
HEAVY CYCLE GAS OIL
LIGHT CYCLE GAS OIL
GAS & GASOLINE TO GAS CONCENTRATION PLANT

132.49X

Figure 5-9.—Diagram of fluid catalytic cracking process.

catalyst flows like a liquid, the process is called fluid catalytic process.

End products of the catalytic cracking process are fuel gas; propane-propylene; butane-butylene, which are fed into the light ends recovery system; pentanes and light gasolines which may be blended directly into motor gasoline; heavy gasoline which after further treatment may be blended into a motor gasoline production system; light gas oil which can be used in various commercial products or returned to the cracking zone; and heavy gas oil which can be charged into thermal cracking units.

Polymerization

Whereas the process of cracking breaks down large, complicated molecules into simpler ones, the process of polymerization combines small molecules into larger ones. Specifically, light olefins are combined to form hydrocarbons of high molecular weight. For example, two molecules of isobutylene (C_4H_8) may be combined to form one molecule of di-isobutylene (C_8H_{16}). The product formed by the union of two identical olefin molecules is referred to as a dimer. That formed by the union of three such molecules is known as a trimer. Two unlike molecules may also be combined resulting in a product known as a copolymer. The process of combining molecules can be continued until large, heavy molecules are formed. Thus, the refiner utilizes byproduct gases to produce a wide variety of products ranging from liquids used as blending in gasolines, to solids which can be used as plasticizers.

Polymerization of propylene and butylene in a mixture to produce a constituent of motor gasoline is the most common polymerization operation. The process most commonly used employs phosphoric acid as a catalyst. The product of the reaction is a mixture of heptenes and other olefins.

Alkylation

Alkylation, like polymerization, is a process whereby hydrocarbons are combined. In the alkylation process, however, paraffinic hydrocarbon (generally considered unreactive) is combined with an olefin to produce a paraffin of branched structure, a highly desirable component of both automotive and aviation gasolines. The result of this combination is known as alkylate. The help of a catalyst is necessary to bring about the reaction.

The process of alkylation makes possible the combination of some of the natural and stable light hydrocarbons with the less stable gases produced by cracking. This process was developed during World War II to increase the availability of source materials required for the manufacture of aviation gasoline. At that time the process was used primarily to produce aviation alkylate from isobutane and butylene; but propylene, ethylene, and pentylene can also be alkylated with isobutane.

There are two types of alkylation processes in wide use. They are: (1) the sulfuric acid process, and (2) the hydrofluoric acid process.

Hydrogenation

The hydrogenation process adds hydrogen to the hydrocarbon molecule. Hydrogenation may be either nondestructive or destructive. In the former, hydrogen is added to the molecule only if, and where, unsaturation with respect to hydrogen exists. The boiling range of the product, resulting from nondestructive hydrogenation, is substantially the same as that of the charge stock.

Nondestructive hydrogenation processes are extensively used in the United States and are known by the trade names as hydroforming, hydrofining, hydrodesulfurization, and other processes some of which have proprietary names. In all of these processes, some degree of dehydrogenation of certain types of hydrocarbons called naphthenes takes place. The hydrogen from the naphthenes attacks sulfur in the charge stock, forms hydrogen sulfide which is removed from the system with the gases. Other hydrogen adds itself to the available olefins present; the remainder of the hydrogen escapes with the light gases. The product of nondestructive hydrogenation has a boiling range little changed from the boiling range of the charge stock. The important changes that take place are: (1) naphthenes are converted to aromatic hydrocarbons which are highly desirable for high performance gasolines, (2) olefins are converted to paraffins which are less susceptible to oxidation, reducing the danger of gum formation in the product, and (3) sulfur has been reduced (although seldom wholly removed).

Destructive hydrogenation can be described as hydrogenation accompanied by cracking. As cracking occurs, hydrogen adds itself to the chains where the rupture occurs. The product of destructive hydrogenation may be lighter than the material charged to the process.

Nondestructive hydrogenation is usually carried out at pressures ranging between 200 and 400 pounds per square inch. Destructive hydrogenation requires much higher pressures. Catalyst is required for both types of hydrogenation.

Destructive hydrogenation has found commercial application in the process known as hydrocracking. In this process a gas oil is cracked in a fixed bed catalytic unit and hydrogen is supplied to the cracking zone. This process, which is now (1965) under extensive development, combines cracking and hydrogenation in a single unit. Superior yields of improved products are the result.

Dehydrogenation

Dehydrogenation is the reverse of hydrogenation. In this process, hydrogen is removed from adjacent carbon atoms of an organic compound with resultant formation of a double bond. Commercial processes now in operation are both catalytic and thermal, and are used principally to dehydrogenate saturated gaseous hydrocarbons to produce starting material for the alkylation process. The process is also used for the production of petrochemical charge stocks, (synthetics, plastics, etc.).

Isomeration

As explained in chapter 3, isomeric compounds are compounds composed of the same elements, united in the same proportions by weight, but differing in one or more properties because of differences in molecular structure. It has also been pointed out that isobutane (a branched-chain paraffin) is isomeric with normal butane (a straight-chain paraffin). Isomerization processes have been developed by the petroleum industry to convert straight-chain hydrocarbons to the valuable branched-chain hydrocarbons which increase the antiknock properties of gasolines. This conversion

63

is brought about in the presence of a catalyst, usually at moderate temperatures and pressures.

In petroleum refining, the isomerization process is applied principally to butane and pentane. The object of isomerizing butane is to obtain isobutane for alkylation and other uses; that of pentane isomerization, to obtain isopentane for blending into gasoline.

Reforming

Reforming is a cracking process employed for the upgrading of stocks with low octane number. It may be either thermal or catalytic and may be mild or severe, depending on the desired end.

Mild reforming is applied to stocks with a boiling range identical or very similar to gasoline. The application of high temperature converts some paraffins to olefins, changes some straight-chain molecules to branched-chain molecules, breaks alkane sidechains from alkane-naphthene molecules, dehydrogenates naphthenes to form aromatic hydrocarbons, and may isomerize some compounds.

Severe reforming is often applied to heavy gasolines with a boiling range of 200-400° F. Enough of the heavier material is cracked to give a finished product with a normal gasoline boiling range. The reactions are the same as in mild reforming except that there is more cracking.

In both thermal reforming and catalytic reforming, the reactions described above take place. In catalytic reforming the order of the reactions is changed since the catalyst promotes certain reactions and does not affect others so readily. Thus, the dehydrogeneration of naphthenes is much more rapid in catalytic reforming than it is in thermal. Also, hydrogen may be recycled in catalytic reforming to bring about a higher degree of sulfur reduction and to convert olefins to paraffins. Catalytically reformed gasoline is thus usually much more saturated (with hydrogen) than is thermally reformed gasoline. Thermal reforming has been largely displaced by the catalytic process.

MANUFACTURE OF PETROLEUM PRODUCTS

The various refining processes which have been described result largely in raw materials which must be further treated and properly blended to produce finished petroleum products. As we have seen in chapter 1, hundreds of products are manufactured from crude petroleum. Only the major steps in manufacturing the more important products are discussed here.

Gasolines

Gasoline for automotive engines is the primary petroleum product in the United States today. Since the appearance of the jet plane in commercial aviation, the market for aviation gasoline has been drastically reduced, dropping the product to a very minor position in the petroleum world. Aviation gasoline has been replaced by jet fuels as the second ranking engine fuel. A large proportion of the high quality materials formerly used in aviation gasolines are now put into fuels for terrestrial vehicles. Many techniques have been developed: (1) to increase the yield of gasoline per barrel of crude in order to meet the increasing demands of the consumer, and (2) to improve the quality of gasolines in order to meet the requirements of modern engines.

In 1904, gasoline comprised less than 10 percent of the total products manufactured from crude petroleum in the United States. (See fig. 5-10.) By 1934, this percentage had increased to more than 40 percent, owing to the rapid development of the internal combustion engine. In 1960, the average refinery yield of gasoline from crude oil was 45.2 percent. Shortly after World War I the demand began to exceed the natural availability of gasoline from crude oil. Thermal cracking was the earliest development for increasing the gasoline yield per barrel of crude and was used commercially following World War I. As explained earlier in this chapter, thermal cracking converts heavy oil fractions to gasoline. The resultant increase in gasoline production and the corresponding decrease in fuel oil production is shown in figure 5-10.

Prior to World War II, gasoline consisted primarily of blends of natural gasoline, straight-run gasoline, and thermally cracked gasoline. With advances in engine design—particularly of aircraft engines—gasolines of higher quality were required. As mentioned previously, the catalytic cracking process results, in general, in products of higher quality. Catalytic cracking is a large source of motor gasoline.

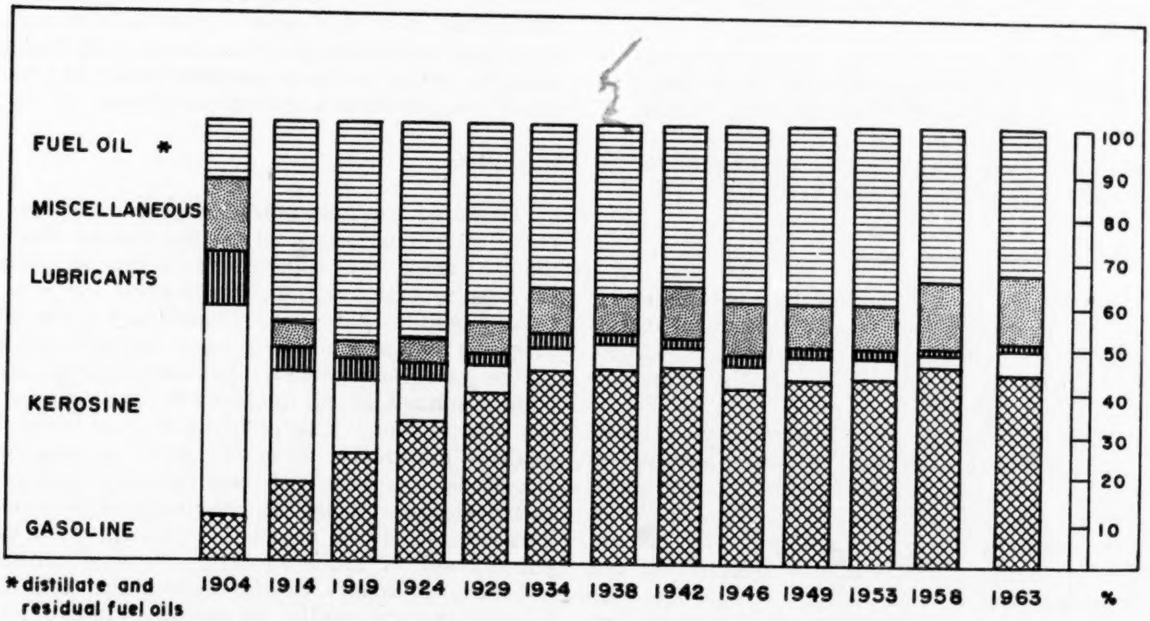


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Figure 5-10.—Petroleum product distribution in the United States.

High quality automotive and aviation gasolines are now made by blending natural gasoline, straight-run gasoline, cracked gasoline, alkylates and reformates. Sometimes one or more of the raw stocks must be chemically treated to remove impurities.

Volatile lead compounds are added in small proportions to increase the antiknock ratings of automotive and aviation gasolines. The gasoline is then dyed various colors for identification purposes.

Lubricating Oils

Reduced crude is the base stock used in the manufacture of lubricating oils. Three or four major steps are necessary in order to prepare end products: (1) vacuum distillation by which the various lube oil cuts are separated from the reduced crude; (2) refining of the various raw fractions to extract wax, asphalt, and impurities which are not desirable in the finished product; (3) blending of the various refined lube oil stocks to the proper viscosity for the finished product, and (4) compounding with additives.

The four major steps are summarized:

1. Vacuum Distillation.—Distillation of reduced crude is carried out under vacuum to avoid cracking which would destroy the lubricating oil. Vacuum distillation of reduced crude results in the production of a certain amount of gas oil which is taken overhead, condensed, and put into other uses. Side streams are taken from various levels in the vacuum tower. In some refineries there may be as few as two such side streams produced, but there may be as many as five. The side steams are called neutral oils. The bottoms from the vacuum tower is called residuum.

2. Refining Lubricating Oils.—The various lubricating oil fractions are refined by subjecting them to various processes each of which removes some undersirable materials that were present in the crude oil. The main processes are generally classified as (a) acid treating, (b) hydrogenation, (c) solvent extraction, (d) dewaxing, and (e) clay treating.

a. Acid Treating.—Concentrated sulfuric acid is applied to the raw lubricating oil or residual. It combines with asphaltic type materials and the combined material, called acid sludge, separates from the oil. The treated oil is then washed with an alkali solution and water to remove traces of acid.

b. Hydrogenation.—Some refiners hydrogenate their lubricating oil stocks for the purpose of improving the color and stability. The hydrogenation required for such stocks is regarded as a milder treatment than is described earlier in this chapter under Conversion Processes. By mild hydrogenation of olefinic materials, compounds in the lubricating oil stock are saturated with hydrogen and certain impurities are removed. The hydrogenated oil is less subject to oxidation and color change after hydrogenation. The process is carried out in the presence of a catalyst.

c. Solvent Extraction.—There are several solvent extraction processes that have almost replaced acid treating of lubricating oil stocks. Some of the extraction processes have patented trade names and are proprietary processes. Among the extraction processes used for treating lubricating oil stocks are: (1) propane deasphalting, (2) furfural extraction, (3) phenol extraction, (4) nitrobenzene extraction, (5) the chlorex process, (6) the Duo-Sol process, and (7) the Edeleanu process.

Essentially all these processes mix a solvent (propane, furfural, phenol, etc.) with the lubricating oil stock whereupon the mixture of oil and solvent separates into two discrete layers—one layer containing solvent and lubricating oil stock, the other containing solvent and extracted material. The two layers are drawn to separate vessels for solvent recovery, after which the refined oil, or raffinate, is sent to further processing into lubricating oil while the extract is sent out of the lubrication oil system to other uses.

Solvent extraction is carried out at elevated, though not drastically high, temperatures.

d. Dewaxing.—Dewaxing is also a solvent extraction process and differs from the solvent extraction described above in that the process is carried out at low temperatures. The lubricating oil stock, after acid treating or solvent extraction, is mixed with a solvent that has low affinity for paraffin wax. The mixture of oil and solvent is chilled to temperatures below 0° F. The wax crystallizes in the mixture and is removed by filtration. Solvents used in various dewaxing processes are propane, acetone, methylethylketone, a mixture of acetone and benzene, and others.

e. Clay Treating.—The final step in refining lubricating oil is clay treating. The clay used in fuller's (tanner's) earth or other clay with suitable adsorptive properties. The clay adsorbs some of the highly colored material in the oil. Also, it removes any acids and traces of resins that may be present.

3. Blending.—Various lubricating oil stock, ranging from relatively light neutral oils to heavy bright stocks, are blended to produce an oil of the desired viscosity range and lubrication characteristics. The blending is a relatively simple operation whereby two or more oil stocks are put together and mixed until they have merged in solution. Mild heating is often used to speed up the blending. Mechanical stirring or agitation with air is used to ensure thorough blending.

4. Compounding.—In the past, mineral lubricating oils were often compounded with animal or vegetable oils. This practice has almost disappeared.

Today, many lubricating oils, particularly those used in internal combustion engines, are compounded with "additives" to improve the properties of the oil.

Additives may be defined for our purposes here, as chemicals which, when used in relatively small proportions, impart improved characteristics to the oils. Some additives are known as pour point depressants and will reduce the pour point of the lubricating oil so as to provide lubrication at low temperatures.

Other additives are known as Viscosity Index improvers and suppress the tendency of the oil to become thin at elevated temperatures.

Other additives inhibit oxidation of the oil in long time use.

Others suppress the formation of emulsions when the oils come in contact with water or other liquids.

Others prevent foaming.

Some provide added protection against rust.

Some impart added strength to the oil film. This is very important in the lubrication of many bearings.

Some impart properties that improve lubrication under heavy load.

And so on through a long list.

Formulation of lubricating oils is usually a trade secret of the manufacturer. Each manufacturer uses such additives in such proportions in his mineral oils as he believes will provide his customers with satisfactory lubrication.

Fuel Oils

Fuel oil is defined as any liquid product which is burned in a heater or firebox for the generation of heat or in an internal combustion engine for the generation of power. Fuel components result from the atmospheric distillation of crude oil, which is sometimes referred to as topped crude or reduced crude and also from distillation of products from refining processes such as cracking. Kerosine and gas oils are also a source of fuel oil components. To meet specifications, the normal procedures of blending and filtering are necessary.

In general, fuel oils may be classified as follows:

1. Distillate fuel oils, which consist of distillates in the kerosine-gas oil boiling range. These may or may not be blends. The most widely used grade is called No. 2 fuel oil. No. 2D diesel fuel is very similar to No. 2 burner fuel.
2. Mixed distillate and heavy residual fuels, which are specially blended to meet equipment specifications. A typical blend is Navy Special Fuel Oil which is tailored for use in combatant ships.
3. Heavy residual fuel oil, which is a heavy residuum which may or may not be blended with cutter stock (gas oil) for ease in handling. In the United States it is normally referred to as "No. 6 fuel oil," if sold for land plants or "bunker fuel oil" (sometimes "bunker C") if for marine applications.

Grease

A lubricating grease is defined as follows: "A solid to semifluid product of dispersion of a thickening agent in liquid lubricant. Other ingredients imparting special properties may be included." Most of the greases produced today use mineral oils as their fluid component. The fluids range in viscosity from as light a product as kerosine up through the heaviest cylinder stocks. In specialty greases the petroleum product may be wax, petrolatum, or asphalt. The thickener may be any material which, in combination with a suitable fluid, will produce a grease structure. Grease thickeners are ordinarily soaps. In addition special modifiers or additives may be added to modify the structure, change the color, or improve the performance of the finished grease.

A typical grease manufacturing procedure would be as follows:

1. Saponification.—A fatty material is added to a portion of the mineral oil. An aqueous solution of a metallic alkali (typical metals—sodium, lithium, calcium, aluminum, or mixtures) is then added and reacted to form a metallic soap. The reaction is carried out with heat and mixing.
2. Dehydration and Cutback.—The wet metallic soap (thickener) is dehydrated by heating and cutback with additional mineral oil to produce the consistency desired in the finished grease. During or following this cutback operation, the grease may be further processed by addition of modifying agents, and kettle milled or homogenized to modify its structure.
3. Deaeration and Filtering.—Entrained air may be removed by deaeration and the grease filtered to remove any contamination that may have been picked up from the raw materials or the processing that might interfere with the performance of the grease.

Waxes

Paraffin and microcrystalline waxes and petrolatum are produced as byproducts in the processing of lubricating oils. Depending upon their type of hydrocarbon constituents and molecular weight, they range from hard solids to semifluids at ambient temperatures. They are used in coatings, rust preventatives, and many other applications.

Asphalt

Asphalt is a natural constituent of most petroleum crude oils, in which it exists in solution. The crude petroleum is refined to separate the various fractions and recover the asphalt. It is produced in a variety of grades and types, ranging from hard brittle solids to almost water-thin liquids.

Asphalt is a strong cement, readily adhesive, highly waterproof and durable. It is also highly resistant to most alkalies, acids, and salts. Because of these properties asphalt's principal use is in road paving. The liquid asphalt products are generally prepared for application by cutting back or blending either with naphtha, kerosine, or gas oils; or by emulsifying them with water.

67

Petrochemicals

Petrochemicals is a popular abbreviation for the term "petroleum chemicals" and covers pure chemical substances produced commercially from petroleum or natural gas. Although many petrochemicals belong in the organic chemical category, inorganic chemicals such as ammonia, carbon black, and sulfur derivatives also can be classified as petrochemicals. World War II served as the beginning of the era in which petroleum began to find its true place as a chemical raw material, entering into such fields as synthetic rubber, plastics, resins, synthetic fibers, and detergents.

Processes used in modern gasoline refining provide many of the basic petrochemical raw materials. Catalytic cracking provides large quantities of low-molecular-weight elefins, especially ethylene, propylene, and butylenes. Also, catalytic reforming produces quantities of benzene, toluene, xylenes, and other higher aromatics for chemical and solvent purposes. Advances in separation processes have allowed the recovery and purification of these products. Special processes have also been commercialized, which convert a rather narrow boiling range petroleum product into a specific petrochemical. For example, severe high temperature cracking of naphthas is used for the production of ethylene.

CHAPTER 6

MEASURING AND SAMPLING PETROLEUM PRODUCTS

A military officer concerned with any phase of petroleum must understand the methods used to compute the volume of petroleum products in storage and transportation tanks. In order to compute the volume accurately, the following facts must be known:

1. Quantity of product in tank,
2. Quantity of water at the bottom of the tank and/or water held in suspension,
3. Average temperature of the product,
4. Specific gravity of the product.

These facts, together with calibration tables and volume correction tables, are used to calculate the volume of any given product, at a standard temperature of 60° F.

Calibration tables are used to convert linear measurements to volume. All petroleum storage tanks and cargo carriers are measured (strapped) for capacity. From these linear measurements, calibration tables (strapping tables) are prepared in terms of barrels or gallons.

Correction to a standard temperature is necessary because of the expansion and contraction of petroleum at different temperatures. Unless this expansion and contraction is taken into consideration, a tank cannot be said to contain a definite amount of oil. Volume correction tables are based on the coefficient of expansion of an oil. The coefficient of expansion is a direct function of its specific gravity or API (American Petroleum Institute) gravity, a physical property discussed in chapter 7.

This chapter is concerned with the standardized methods employed to manually measure the quantity of a product in a given tank, the amount of water in the tank, and the temperature of the product. It is concerned also with basic sampling principles.

MEASUREMENT OF QUANTITY

Remote tank gage and temperature reading and recording devices have been developed in recent years which have demonstrated a high degree of accuracy. Some types of this equipment have been installed at several Navy fuel facilities.

The most common types of remote gage reading devices make use of float equipment for determining the tank liquid level height. Liquid level measurements and temperature data can be transmitted electronically to a central control point, on demand, where it may be directly observed or recorded for later use. Primary use of this equipment is for quickly determining: (1) present stock position; (2) that large transfers are proceeding according to plan; and (3) the existence of leaks in tanks. However, these devices are not yet used by the Navy in determining quantities for accounting purposes.

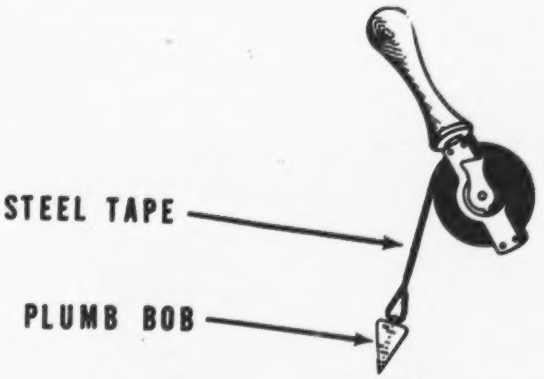
Gaging

Gaging is the mechanical measurement in feet, inches, and fractions of an inch of the quantity of a product in a storage tank, tank car, or tank truck. Gaging is performed with a wooden stick or a steel tape marked in feet, inches, and eighths of an inch. In the latter case, the tape is wound on a hand reel that comes equipped with a brass plumb bob or suitable weight to hold the tape taut. (See fig. 6-1.) The tape is fastened to the bob with a snap, and the tape markings include the length of the bob.

There are two basic types of procedures for obtaining gages and the results are known as ullage (or outage) gage, and innage gage.

Ullage (Or Outage) Gage

An ullage gage is the distance from a given point at the top of the container down to the



10.33
Figure 6-1.—Tank gaging tape.

surface of the liquid. This measurement is usually taken on ships' tanks. In taking ullage, the tape is gradually lowered and swung back and forth until the tip of the bob breaks the surface and causes a ripple. At this point the tape is held steady and a reading taken at a reference point at the gage hatch. The steps in measuring ullage are shown in figure 6-2.

Innage Gage

An innage gage is the depth of liquid in a tank, measured from the surface of the liquid to the tank bottom. This measure is commonly taken on vertical shore tanks above and below ground. Steps in measuring innage are shown in figure 6-3.

Frequency of Gaging

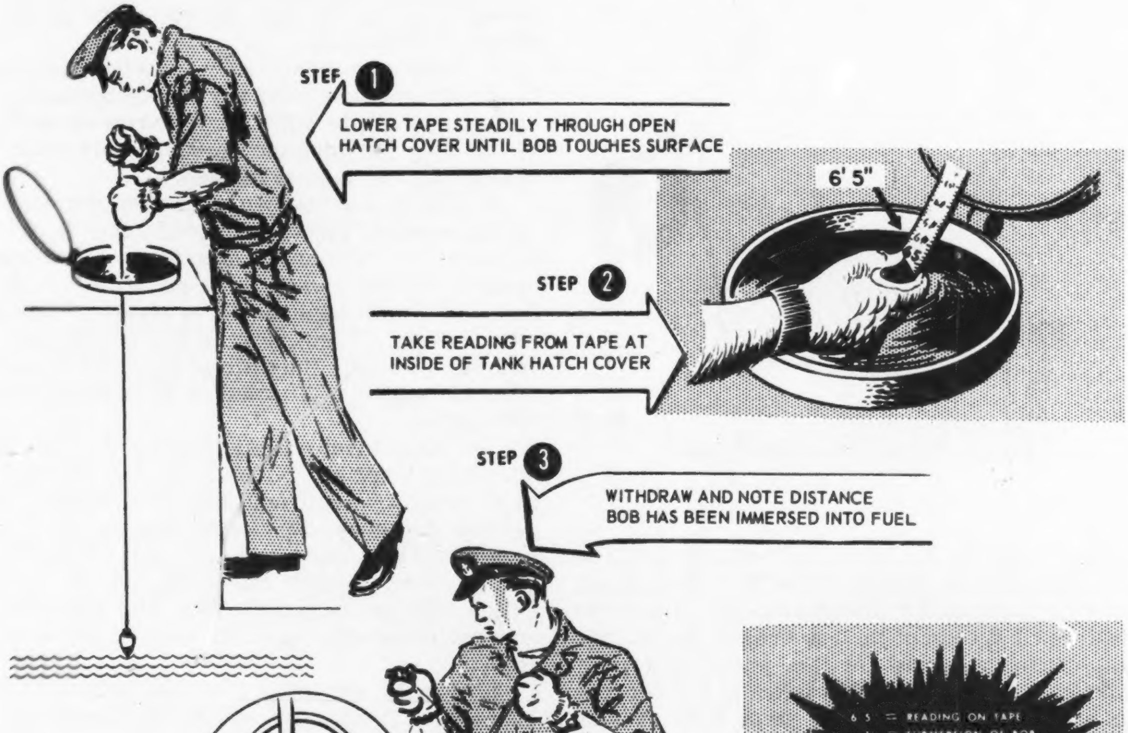
The frequency of taking tank gages varies with the activity of the depot. All gages are to be taken manually unless otherwise directed by the fuel officer. The following suggestions are practical minimums:

1. Inactive tanks should be gaged at least once a week.
2. Tanks first filled or filled after having been empty for some time should be gaged once a day until it appears that there is no leakage.
3. In case the gaging record of any tank appears irregular, all other tanks into or out of which leakage might have occurred should be gaged for check.
4. Every tank that is apt to be worked or issued from during the day should be gaged at the start of the day.
5. Tanks involved, or that may be used, must be gaged before starting any receipt by the depot. Such gages will be witnessed by a representative of the ship (or pipeline carrier), and must be verified by two men at the depot.
6. Tanks must be gaged after the completion of any receipt. The final official gage should be deferred for 12 hours, if practicable, to ensure against errors caused by foam or air. A preliminary check gage should be taken 30 minutes after receipt. Then, if it is not practicable to wait for 12 hours, the official gage may be taken after two gages at 30-minutes successive intervals agree.
7. Tanks involved must be gaged before and after any issue or transfer. Such gages should be verified by a second man. The agency receiving the issue may verify the gage or it may be verified by an inspector acting for the receiver of the issue. In many cases this outside verification will not be practicable. There should be no real necessity for it in case of intra-Navy issues.
8. Should any depot load tank ships for offshore delivery, gages will be witnessed by an inspector.

Measurement of Water

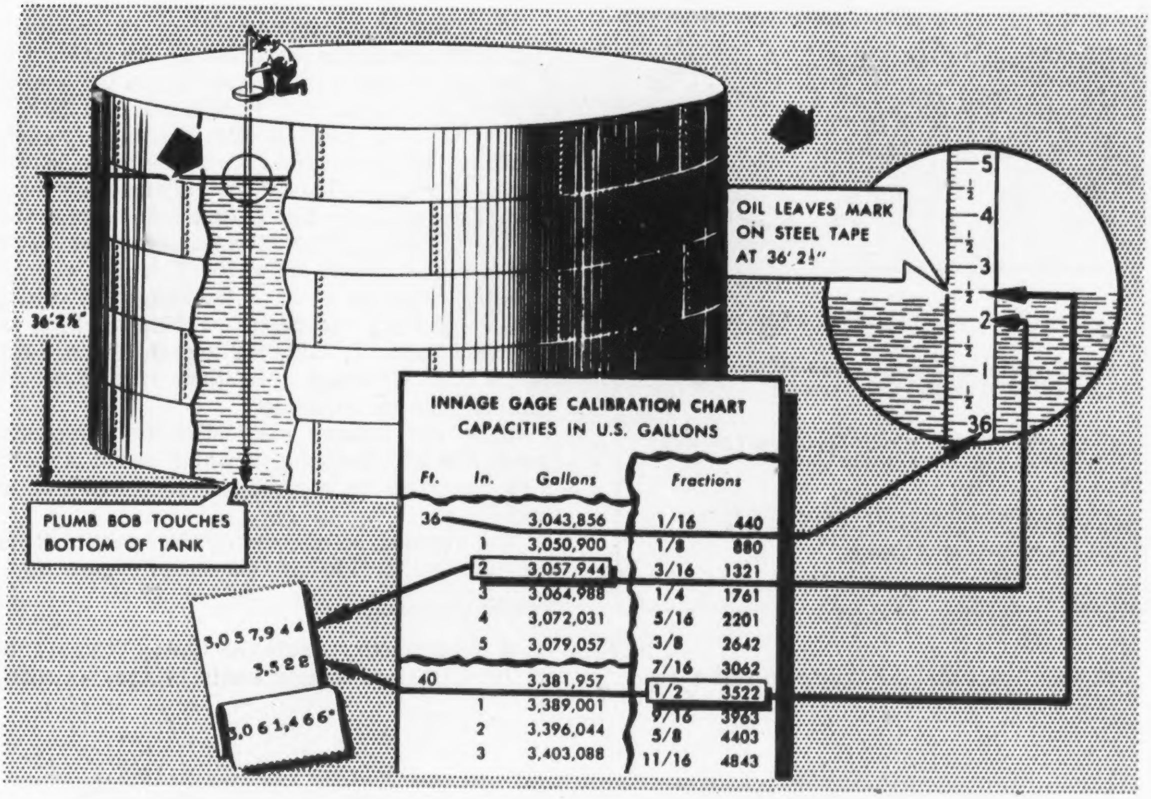
In many cases, there is a layer of free water in the tank bottom. The depth of this bottom water is obtained by taking a water cut. This is usually accomplished by coating the plumb bob or gaging tape with water-finding paste.

To obtain the water cut in a fuel oil tank, the bob must be allowed to rest on the bottom of the tank, as illustrated in figure 6-3, from 30 to 60 seconds. For heavy fuel oils, it may be necessary to cover the water-finding paste with lubricating oil. After the bob is withdrawn, the fuel oil is washed off gently with diesel oil in order to reveal the water mark, shown by the change in color of the water-finding paste. For diesel fuel oil or gasoline the water cut is obtained more quickly. In this case the water-finding paste need not be covered with lubricating oil. The water cut in a tank is subtracted from the total quantity of the product as shown by the innage or ullage gage to determine the actual amount of a petroleum product in a tank. The amount of water should be calculated at the same time and then reported. The steps for taking a water cut are shown in figure 6-4.


STEP ①
LOWER TAPE STEADILY THROUGH OPEN HATCH COVER UNTIL BOB TOUCHES SURFACE
6' 5"
STEP ②
TAKE READING FROM TAPE AT INSIDE OF TANK HATCH COVER
STEP ③
WITHDRAW AND NOTE DISTANCE BOB HAS BEEN IMMERSED INTO FUEL
6 5 = READING ON TAPE
1 = SUBMERSION OF BOB
6 4 = DISTANCE FROM FUEL SURFACE TO TANK OVERHEAD
STEP ④ SUBTRACT
ULLAGE GAGE CALIBRATION CHART
CAPACITIES IN U. S. GALLONS
IN
5 FT
IN
6 FT
4
16276
STEP ⑤
APPLY FIGURE TO ULLAGE TABLE TO FIND AMOUNT OF FUEL

10.34

Figure 6-2.—Steps in measuring ullage.


36'2½"
PLUMB BOB TOUCHES BOTTOM OF TANK
OIL LEAVES MARK ON STEEL TAPE AT 36' 2½"
5
½
4
½
3
½
2
½
1
½
36
INNAGE GAGE CALIBRATION CHART
CAPACITIES IN U.S. GALLONS
Ft. In. Gallons
36 3,043,856
1 3,050,900
2 3,057,944
3 3,064,988
4 3,072,031
5 3,079,057
40 3,381,957
1 3,389,001
2 3,396,044
3 3,403,088
Fractions
1/16 440
1/8 880
3/16 1321
1/4 1761
5/16 2201
3/8 2642
7/16 3062
1/2 3522
9/16 3963
5/8 4403
11/16 4843
3,057,944
3,522
3,061,466

132.53

Figure 6-3.—Steps in measuring innage.

Water in suspension is determined by the centrifuge method, described briefly in chapter 7, "Testing Petroleum Products."

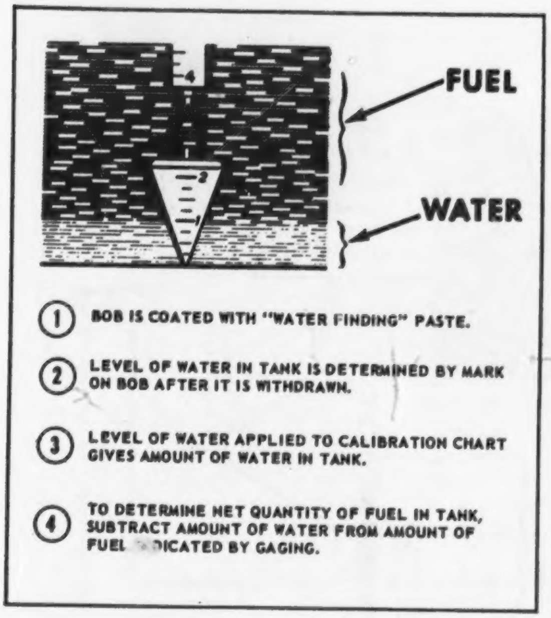
Measurement of Temperature

The average temperature of a product is required to calculate its volume at a standard temperature of 60° F. It is important to determine temperatures accurately because an error in determining the average temperature of a product causes errors of considerable magnitude in calculating the volume of a product at 60° F.

To arrive at an accurate average, temperatures of liquid petroleum products are determined at specified locations in tanks, ships, barges, tank cars, and tank trucks. Temperature readings are then averaged arithmetically to obtain the average temperature.

The thermometer most commonly used for taking tank temperatures is a standard cup type of 0° to 180° F range, marked to 1° F divisions, with an open metal cup of about 100-cc capacity surrounding the bulb. For heavy fuel oil, or when accurate results are wanted more quickly in a tank that is not at approximately the same temperature throughout, a special trap thermometer is used. This thermometer is suspended at least a foot from the shell. For heavy fuel oils the thermometer may be suspended in the tank at all times. In tanks of over 5000-barrel capacity, several openings are usually provided through which temperatures are taken.

Considerable time is required for a thermometer to reach equilibrium in fuel oil. The length of time varies greatly with conditions; it seldom will be under 5 minutes, and may be as much as 20 minutes. In a diesel fuel oil or gasoline tank, less time is required.



① BOB IS COATED WITH "WATER FINDING" PASTE.

② LEVEL OF WATER IN TANK IS DETERMINED BY MARK ON BOB AFTER IT IS WITHDRAWN.

③ LEVEL OF WATER APPLIED TO CALIBRATION CHART GIVES AMOUNT OF WATER IN TANK.

④ TO DETERMINE NET QUANTITY OF FUEL IN TANK, SUBTRACT AMOUNT OF WATER FROM AMOUNT OF FUEL INDICATED BY GAGING.

10.35

Figure 6-4.—Steps in taking a water cut.

Volume Correction

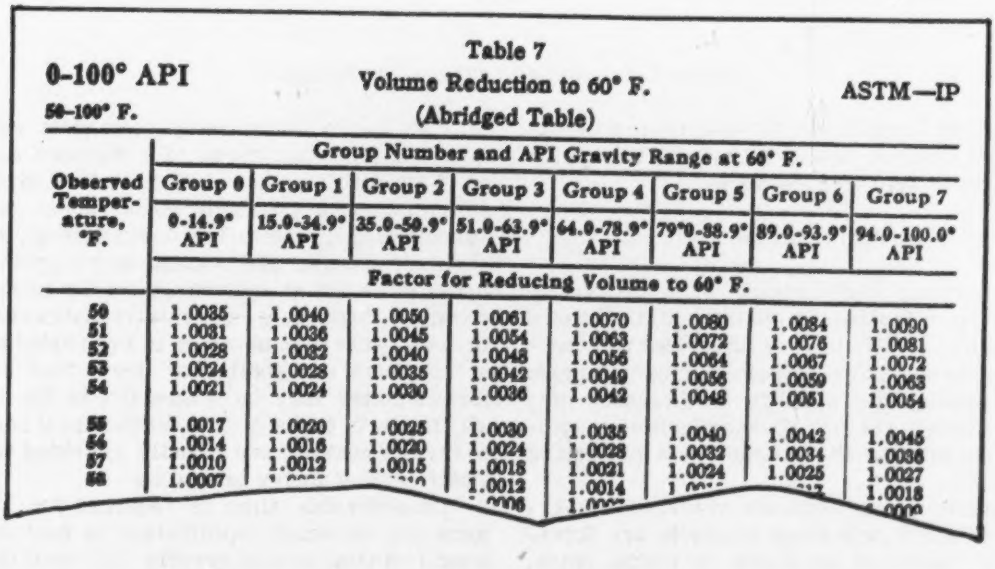
The unit of measurement for determining quantities of bulk petroleum products both within and without the continental U.S. is the barrel of 42 U.S. gallons at a temperature of 60° F. All corrections on fuel oils, diesel fuel oils, gasolines and other light fuels are made in accordance with ASTM-IP Petroleum Measurement Tables. Table No. 7, figure 6-5, gives the factors for converting oil volumes observed at temperatures other than 60° F to the corresponding volumes at 60° F for ranges of values of API gravity at 60° F. This table is an abridged form of Table 6a and is intended for use where accuracy less than that given by Table 6a can be tolerated.

Thus the volume correction of a product, having the characteristics which would place it in Group No. 2 would be determined as shown in figure 6-6.

The method of converting the quantity from gallons to barrels is shown in figure 6-7.

Weight Conversion

In many ports outside the United States, fuel oil is sold on a weight basis of tons or other



0-100° API
50-100° F.

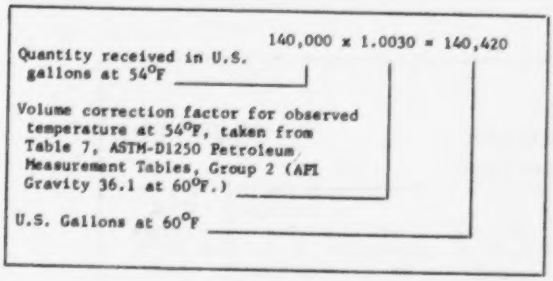
Table 7
Volume Reduction to 60° F.
(Abridged Table)

ASTM—IP

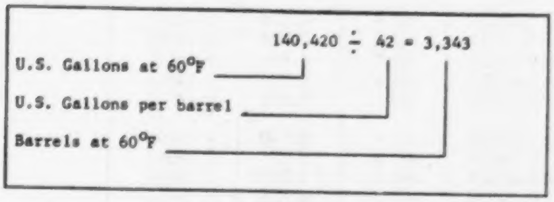
Observed Temperature, °F.	Group Number and API Gravity Range at 60° F.							
	Group 0	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
	0-14.9° API	15.0-34.9° API	35.0-50.9° API	51.0-63.9° API	64.0-78.9° API	79°0-88.9° API	89.0-93.9° API	94.0-100.0° API
	Factor for Reducing Volume to 60° F.							
50	1.0035	1.0040	1.0050	1.0061	1.0070	1.0080	1.0084	1.0090
51	1.0031	1.0036	1.0045	1.0054	1.0063	1.0072	1.0076	1.0081
52	1.0028	1.0032	1.0040	1.0048	1.0056	1.0064	1.0067	1.0072
53	1.0024	1.0028	1.0035	1.0042	1.0049	1.0056	1.0059	1.0063
54	1.0021	1.0024	1.0030	1.0036	1.0042	1.0048	1.0051	1.0054
55	1.0017	1.0020	1.0025	1.0030	1.0035	1.0040	1.0042	1.0045
56	1.0014	1.0016	1.0020	1.0024	1.0028	1.0032	1.0034	1.0036
57	1.0010	1.0012	1.0015	1.0018	1.0021	1.0024	1.0025	1.0027
58	1.0007	[illegible]	[illegible]	1.0012	1.0014	[illegible]	[illegible]	1.0018
				[illegible]	[illegible]			[illegible]

132.55

Figure 6-5.—Portion of Table 7, ASTM-D1250 Petroleum Measurement Tables.


140,000 x 1.0030 = 140,420
Quantity received in U.S. gallons at 54°F
Volume correction factor for observed temperature at 54°F, taken from Table 7, ASTM-D1250 Petroleum Measurement Tables, Group 2 (API Gravity 36.1 at 60°F.)
U.S. Gallons at 60°F

10.31.0
Figure 6-6.—Example of volume correction to 60° F.



10.31.0
Figure 6-7.—Example showing computation from gallons to barrels.

weight standards. In arriving at the weight delivered, the specific gravity at 60° F is generally used, but this temperature may vary in some areas. When quantity is computed on a weight basis, volume determinations computed in accordance with figure 6-6 will first be made and subsequently converted to the designated weight standard in accordance with the abridged ASTM-D1250, Table 8 shown in figure 6-8. An example of weight calculation is shown in figure 6-9.

SAMPLING

Correct sampling procedures are necessary to provide truly representative samples that are used primarily for determining the physical and chemical properties of products. In this connection, sampling is an important phase of quality surveillance. Correct sampling procedures are also required to provide samples used for obtaining the gravity and the suspended water and sediment of the product, both of which are required for computing volume accurately.

Types of Samples

The portions taken for samples must represent the general character and average condition of the lot being sampled. Various types of samples may be taken. Among the more common types are: average samples, upper samples, middle samples, lower samples, and composite samples.

Average Sample

An average sample is one so taken as to contain parts from all sections of the container or pipe, in proportion to the volume of each part. However, it is practically impossible to obtain a true average sample, except perhaps, through a continuous sampling connection from a vertical run in a pipeline with specially constructed draw-off pipes, or by vigorously agitating and stirring the contents of a vessel and drawing off a sample while the contents are agitated.

Upper Sample

An upper sample is one taken from the upper third of the fluid (at a point equal to 10 percent of the depth of a uniform cross-section vessel, or 10 percent of the diameter of a horizontal cylindrical tank).

Middle Sample

A middle sample is one taken at half the depth of the material.

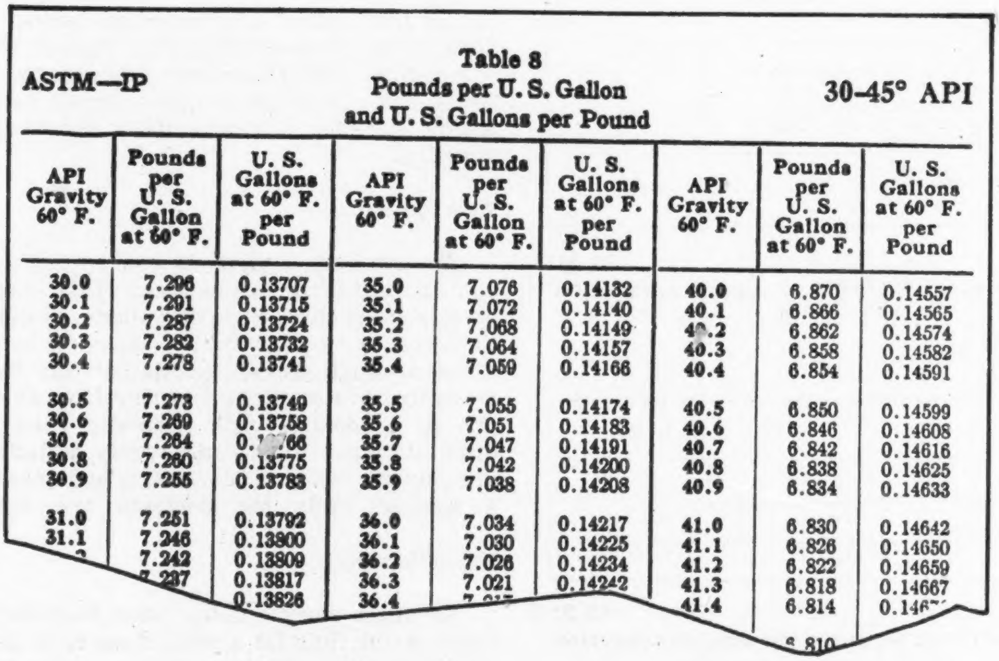
Lower Sample

A lower sample is one taken at a point 10 percent of the depth of a uniform cross-section vessel, or 10 percent of the diameter of a horizontal cylindrical tank, above the bottom of the vessel.

Composite Sample

A composite sample is a mixture of upper, middle, and lower samples containing, for vessels of different shapes, volume proportions which correspond approximately to the volumes of the material at these levels:

For uniform cross-section vessels: upper sample, 1 part; middle sample, 3 parts; lower sample, 1 part.



ASTM—IP

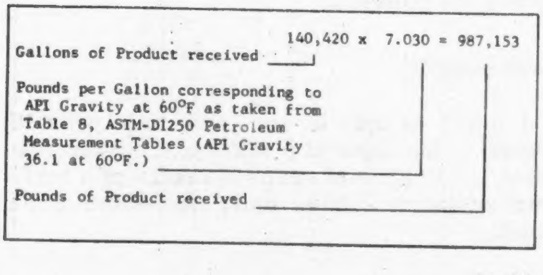
Table 8
Pounds per U. S. Gallon
and U. S. Gallons per Pound

30-45° API

API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound
30.0	7.296	0.13707	35.0	7.076	0.14132	40.0	6.870	0.14557
30.1	7.291	0.13715	35.1	7.072	0.14140	40.1	6.866	0.14565
30.2	7.287	0.13724	35.2	7.068	0.14149	40.2	6.862	0.14574
30.3	7.282	0.13732	35.3	7.064	0.14157	40.3	6.858	0.14582
30.4	7.278	0.13741	35.4	7.059	0.14166	40.4	6.854	0.14591
30.5	7.273	0.13749	35.5	7.055	0.14174	40.5	6.850	0.14599
30.6	7.269	0.13758	35.6	7.051	0.14183	40.6	6.846	0.14608
30.7	7.264	0.1[illegible]66	35.7	7.047	0.14191	40.7	6.842	0.14616
30.8	7.260	0.13775	35.8	7.042	0.14200	40.8	6.838	0.14625
30.9	7.255	0.13783	35.9	7.038	0.14208	40.9	6.834	0.14633
31.0	7.251	0.13792	36.0	7.034	0.14217	41.0	6.830	0.14642
31.1	7.246	0.13800	36.1	7.030	0.14225	41.1	6.826	0.14650
	7.242	0.13809	36.2	7.026	0.14234	41.2	6.822	0.14659
	7.237	0.13817	36.3	7.021	0.14242	41.3	6.818	0.14667
		0.13826	36.4			41.4	6.814	
							6.810	

132.58

Figure 6-8.—Portion of Table 8, ASTM-D1250 Petroleum Measurement Tables.



140,420 x 7.030 = 987,153

Gallons of Product received

Pounds per Gallon corresponding to API Gravity at 60°F as taken from Table 8, ASTM-D1250 Petroleum Measurement Tables (API Gravity 36.1 at 60°F.)

Pounds of Product received

10.32.0

Figure 6-9.—Example of weight calculation.

For horizontal cylindrical tanks (assumed full); upper sample, 1 part; middle sample, 8 parts; lower sample, 1 part.

For horizontal cylindrical tanks that are only partially filled, these sampling levels and composite sample mixtures cannot give samples that are substantially proportionate to the volumes at the different depths unless the tanks are filled to at least 80 percent of the diameter. Table 6-1 gives a set of substantially correct sampling levels and sample quantities for partially filled horizontal tanks, which may be used, employing values in the tabulation that lie nearest to the actual filling depth.

Sampling Procedures

There is a variety of sampling procedures, each of which is suitable for sampling a number of specific products under definite storage, transportation, or container conditions. Since description of these procedures is beyond the scope of this book, only one common method is mentioned.

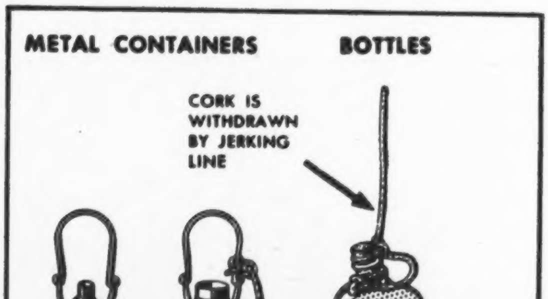
Customarily, samples are drawn from ship tanks, barges, and large shore tanks by lowering and raising a bottle while allowing it to fill. Glass bottles of 1 quart to 1 gallon capacity

Table 6-1.—Sampling Levels and Sample Quantities for Partially Filled Horizontal Cylindrical Tanks

Liquid depth (percentage of diameter)	Sampling level (percentage of diameter above bottom)			Quantity of sample to be taken at each sampling level		
	Upper	Middle	Lower	Upper	Middle	Lower
10			5			10 parts.
20			10			Do.
30		20	10		6 parts	4 parts.
40		25	10		7 parts	3 parts.
50		30	10		8 parts	2 parts.
60	55	35	10	1 part.	do	1 part.
70	65	40	10	do	do	Do.
80	75	45	10	do	do	Do.
90	85	50	10	do	do	Do.
100	90	50	10	do	do	Do.

are commonly used. (Metal containers, constructed with a bail are sometimes used.) Sampling bottles are suspended in the tank by a cord tied to the cork and secured around the neck with two clove hitches, slack being allowed between cork and bottle as shown in figure 6-10. The free end of the line below the neck of the bottle is looped in a hitch around the lower part of the bottle and terminates in a lead weight heavy enough to sink the entire assembly. When the bottle is lowered to the desired depth (usually near the bottom of the tank, but above any water line), the cork is readily withdrawn by jerking the line. The bottle is then raised steadily at such a rate that it is not quite full when it breaks the surface. Samples obtained in this way are considered to be average samples, but obviously the proportions are not related to the tank volume at the various levels.

During sampling, every precaution must be taken to ensure that the sampling apparatus and the samples themselves are neither contaminated nor altered by any material not representative of that being sampled. The sampling apparatus should be thoroughly clean, dry, and free from any substance that will dissolve into or color the product being sampled. Before the sample is drawn, the sample container must be rinsed with the product being sampled, taking special care to ensure that no lint or fibrous material is present. After collection of the sample, the container must be closed immediately.


METAL CONTAINERS
BOTTLES
CORK IS WITHDRAWN BY JERKING LINE
SMALL MOUTH CONTAINER FOR GASOLINES AND LIGHT FUELS
LARGE MOUTH CONTAINER FOR HEAVY FUELS
WEIGHT TO SINK BOTTLE

132.60

Figure 6-10.—Sampling containers.

Disposition of Samples

Samples are used for one or more of the following purposes:

1. Visual examination
2. Laboratory test
3. Preservation for record
4. Check and referee tests

Retain samples are held for the protection of the supplier, loading terminal, and inspector. These samples are marked, showing the sources of the sample and the date taken. They are then stored and held for the length of time prescribed for the particular product.

CHAPTER 7

TESTING PETROLEUM PRODUCTS

This chapter covers, in a general way, the standard test methods employed to determine the quality and performance characteristics of various petroleum products. Detailed descriptions of standard procedures for these test methods are set forth in publications of the American Society for Testing and Materials and in Federal Test Method Standard No. 791.

The American Society for Testing and Materials (ASTM) is an international technical society. An important function of this society is the standardization of specifications and methods of testing. The development of standards is carried out by various technical committees, each of which functions in a prescribed field and under definite regulations to ensure adequate representation of producers, consumers, and general interest. Acceptance of proposed standards for publication and their adoption is by action of the Society upon recommendation of the committees. The Society is recognized as the authority on methods of testing petroleum and its products. Methods of tests and specifications pertaining to petroleum are published in the Book of ASTM Standards, (Part 17) Petroleum and issued annually.

The Federal Test Method Standard No. 791 is composed of standard test methods for sampling, inspecting, and testing lubricants, liquid fuels, and related products. It is issued pursuant to the Federal Property and Administration Services Act of 1949, as amended, and its application to the purchase of petroleum products is mandatory on all Federal agencies. Some methods in this standard are identical to those published by the ASTM. In such cases the standard only provides a cross reference to the identical ASTM method. The test methods of this standard when cited in a petroleum product specification, form an integral part of that specification.

Tests of petroleum products are used in the development, manufacture, and application of petroleum products. Several hundred physical, chemical, and performance tests have been approved by ASTM and new tests are constantly being developed.

The following discussion is limited to a survey of the tests most commonly employed in determining the performance characteristics and the quality of various petroleum products. A list of tests and the petroleum products for which they are most commonly used is shown in table 7-1.

GRAVITY

Specific gravity is the ratio of the weight of a given volume of a substance to the weight of an equal volume of water. Normally, the gravity of petroleum products is expressed in degrees API, in accordance with the API (American Petroleum Institute) scale. The relationship of specific gravity to API gravity, expressed as degrees API, is given in the following formula:

$$\text{Specific Gravity} = \frac{141.5}{131.5 + \text{degrees API}}$$

From this formula it can be seen that an oil of 10° API gravity is equal to 1, or the specific gravity of water. All gravity determinations are correlated with a specific temperature and are generally corrected to a standard temperature of 60° F by use of tables.

Either the specific gravity or API gravity of petroleum products must be determined to make volume corrections at different temperatures. (See ch.6.) Gravity may also be a rough index of whether an oil is naphthenic or paraffinic, but other tests are more indicative of the quality characteristics of the product.

Measurements of both specific gravity and API gravity are made by use of hydrometers. Hydrometers marked according to the API scale

Table 7-1.—Common Tests Made on Petroleum Products

	Crude Petroleum	Gasoline and Naptha	Illuminating Oil	Fuel Oil and Gas Oil	Lube Oil	Transformer Oil	Grease	Jet Fuel
Gravity	X	X	X	X	X	X		X
Flash Point	(1)		X	X	X	X		X(2)
Fire Point	(1)		X	X		X		
Water and Sediment	(1)	(1)	(1)	X				X
Viscosity	X		(1)	X	X	X		X
Cloud and Pour Point	(1)		(1)	X	X	X		
Steam Emulsion No.	(1)				X	(1)		X
Sulfur Content	X	X	X	X	(1)			X
Vapor Pressure		X						X(3)
Distillation		X	(1)	(1)				X
Knock Characteristics		X						
Cetane Number				X				X
Thermal Value				X				
Neutralization and Saponification No.					(1)			
Color		X	X	(1)	X	X		X
Ash Content	X		(1)	X	X	X		
Carbon Residue				X	X			
Oxidation	(1)	X	(1)	X	X	X		X
Corrosion		X		X	X	X		X
Gum		X						X
Freezing Point		X						X
Water Separometer Index								(1)
Thermal Stability								(1)
Smoke Point								(1)(2)
Smoke Volatility Index								(1)(3)
Penetration							X	
Dropping Point							X	

X Usually used

(1) Sometimes used

(2) JP-5 only

(3) JP-4 only

are normally used in the petroleum industry. However, if such hydrometers are not available, ordinary hydrometers may be used and conversions made to degrees API by use of the above formula expressed as follows:

$$\text{Degrees API} = \frac{141.5}{\text{specific gravity}} - 131.5$$

FLASH AND FIRE POINTS

The flash point of a petroleum product is the temperature at which it first gives off sufficient flammable vapor to ignite. The fire point is the temperature at which its vapors will contine to burn. The fire point of any product ranges from 10° to 70° higher than its flash point.

Flash and fire points are used principally to indicate the fire hazards of petroleum products.

Petroleum products vary greatly in their flash and fire points. Gasolines and JP-4 jet fuel have flash points well below freezing, while lubricating oils have flash points normally ranging from 275°F to 700°F. The specification for JP-5 jet fuel requires a flash point of 140°F. Because of this high flash point JP-5 is relatively safe for shipboard stowage in unprotected tanks and is stored on board aircraft carriers and other ships.

There are three principal methods of determining flash and fire points: (1) Cleveland open cup method; (2) Pensky-Martens closed cup method; and (3) TAG closed cup method. (TAG is the contraction of Tagliabue, a manufacturer of testing apparatus.) The open cup method is commonly used for determining flash and fire points of lubricating oils, while either of the closed cup methods is used for highly volatile products. All three methods use the application of heat to the products being tested. While heat is being applied, a flame is passed periodically across the surface of the open cup—or across an opening in the cover of the closed cup—until a flash is observed.

VISCOSITY

The viscosity of a liquid is a measure of its internal friction, or its resistance to flow. A liquid has high viscosity if it flows sluggishly, like cold molasses; it has low viscosity if it flows freely, like water.

Viscosity of a lubricating oil at operating temperatures should be high enough for the oil to maintain a fluid film regardless of the load imposed upon it. It should not, however, be so high that it causes drag or excessive fluid friction (friction within the oil itself). Fluid friction is a source of power loss and such friction, if excessively high, raises the temperature of the oil. Viscosity at operating temperatures varies with temperature changes, being higher at low temperatures and lower at high temperatures. The viscosity at operating temperatures determines the fluid friction, the heat generated in the bearing, and the rate of flow of the oil under given conditions. Therefore, viscosity of lubricating oils at operating temperatures must be known in order to select the proper lubricating oil for a specific purpose.

Absolute viscosity is the force required to move a plane surface area of one square centimeter over another plane surface at the rate of one centimeter per second when the two surfaces are separated by a layer of liquid one centimeter in thickness. The unit of absolute viscosity is the poise. The ratio of absolute viscosity to the specific gravity of the oil at the temperature at which the viscosity is measured is kinematic viscosity. The unit of kinematic viscosity is the stoke.

Although determination of absolute viscosity will give extremely accurate values, the method is difficult. Consequently, kinematic viscosity is measured when extremely accurate determinations are necessary. For practical purposes, however, viscosity of petroleum products is usually determined by employing a viscosimeter to determine the time necessary for a given quantity of oil to flow through a standardized capillary tube. Although there are several types of viscosimeters, the ones most commonly used in the United States are: (1) the Saybolt Universal viscosimeter, and (2) the Saybolt Furol viscosimeter. Viscosity is then reported as Saybolt viscosity.

Saybolt Universal

The Saybolt Universal viscosimeter consists of an oil tube, bath, receiver, thermometers, timers, and withdrawal tube. (See fig. 7-1.) When using this instrument, the oil to be tested is placed in the oil tube, and the bath is brought to a given temperature (usually 100°, 130°, or 210° F). A cork stopper at the bottom of the tube is then removed and the oil allowed to flow into a 60-cc graduate. The time, in seconds, required for 60 cc of oil to flow through

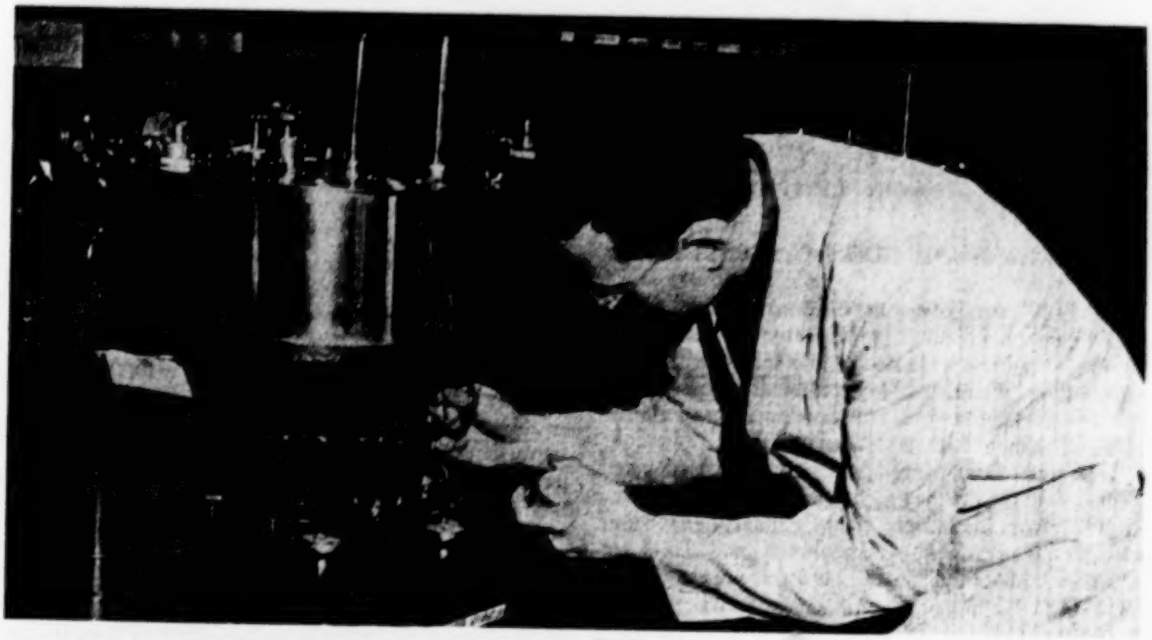


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Figure 7-1.—Saybolt Universal viscosimeter.

the opening is measured and recorded. This time, at the temperature of the bath, is the viscosity of the oil, expressed in Saybolt Universal seconds.

Saybolt Furol

The Saybolt Furol viscosimeter is generally used for viscosity determinations of extremely viscous liquids such as fuel and road oils (the word Furol being a contraction of the phrase fuel and road oils). The Furol viscosimeter is similar to the Universal viscosimeter, but the opening at the bottom of the former is larger in order to facilitate the flow of heavier liquids. The instrument is operated in the same way as the Universal viscosimeter, but Saybolt Furol viscosities are usually obtained at 122° F. The Saybolt Furol viscosity figure for a given oil is usually about one-tenth that obtained when the Saybolt Universal instrument is used.

The Society of Automotive Engineers (SAE) has established an arbitrary system for classifying motor oils according to their viscosities. The SAE Viscosity Numbers which have been used since 1938, and their corresponding Saybolt viscosities, are shown in table 7-2. In addition to SAE Viscosity Numbers for motor oils, there are also SAE Viscosity Numbers for transmission and rear-axle lubricants. It must be remembered that these numbers are based on viscosities alone and that no other factors are considered in the classification.

VISCOSITY INDEX

The viscosity index (V.I.) of an oil is an empirical number indicating the effect of change of temperature on the viscosity of an oil. A low viscosity index signifies a relatively large change of viscosity with changes of temperature. In other words, an oil which becomes extremely thin at high temperatures and extremely thick at low temperatures is said to have a low viscosity index. Contrariwise, a high V. I. signifies relatively little change in viscosity with change of temperature.

An ideal oil for most purposes would be one maintaining a constant viscosity despite temperature changes. The importance of viscosity index can be illustrated readily by automotive lubricants. An oil having a high V. I.

Table 7-2.—SAE Viscosity Numbers of Motor Oils and Corresponding Saybolt Viscosities

SAE Viscosity Number	Viscosity Range, Saybolt Universal Seconds			
	Min.	At 130° F Max.	At 210° F Min.	At 210° F Max.
10	90	Less than 120 . . .	. . . . .	. . . .
20	120	Less than 185 . . .	. . . . .	. . . .
30	185	Less than 255 . . .	. . . . .	. . . .
40	255	. . . .	. . . . .	Less than 80.
50	. . . . .	. . . .	80	Less than 105.
60	. . . . .	. . . .	105	Less than 125.
70	. . . . .	. . . .	125	Less than 150.

resists excessive thickening when the engine is cold and consequently ensures rapid starting and prompt circulation; it resists excessive thinning when the motor is hot and thus provides full lubrication and prevents excessive oil consumption.

Another example of the importance of viscosity index is the necessity for high V. I. hydraulic oils for military aircraft since hydraulic control systems may be exposed to temperatures ranging from below −67°F at high altitudes to over 100° F on the ground. For the proper operation of the hydraulic control system, the hydraulic fluid must be of sufficiently high viscosity index to perform its functions at the extremes of the expected temperature range.

The viscosity index of an oil may be determined if its viscosity at any two temperatures is known. Tables, based on a large number of tests, are issued by the ASTM. These tables permit calculation of V. I. from known viscosities.

CLOUD AND POUR POINTS

The cloud point of an oil is the temperature at which its paraffin content, normally held in solution, begins to solidify and separate in tiny crystals, causing the oil to appear cloudy or hazy. The pour point of an oil is the lowest temperature at which it can be poured.

Determination of the cloud point is of value if the oil is to be used in wick-feed oilers. For example, an oil having a high cloud point would readily form wax crystals. These crystals would clog the wick and prevent the passage of oil. Thus, necessary lubrication would not be provided.

The pour point is of greater value and has a wider range of application than the cloud point. The pour point is of particular significance when a lubricant is to be used in machines exposed to low temperatures. For example, fighting aircraft, which are flown at high altitudes where low temperatures exist, must use hydraulic oils having very low pour points. However, neither the pour point alone, nor the results of any other single test, can be taken as a positive measure of the performance of an oil under all conditions of service. Other factors—such as the size and shape of the oil container, the force exerted upon the oil, and the nature of the oil's physical structure when solidified—must be taken into consideration.

Refrigeration equipment which holds rows of jars, each fitted with a thermometer, is used in determining both cloud and pour points. Samples to be tested are placed in the jars and the pour and cloud points ascertained. In determining cloud point, the jars are chilled at a specified rate to −30° F. Readings are taken until the bottom of the oil sample becomes cloudy, at which temperature the oil has reached its cloud point. The jars are then chilled at a specified rate down to −60° F or until a point is reached at which the container can be held in a horizontal position for five seconds with no apparent movement of oil.

The pour point is the temperature 5° F above this point.

STEAM EMULSION NUMBER

Emulsion is the dispersion of one liquid in another. Although oil and water do not mix, they can be emulsified, the oil being suspended in the water in minute particles. The ability of an oil to become suspended in water in minute particles is known as its emulsibility. Oils of good emulsibility are desirable in metal cutting and grinding operations. However, the reverse is true in the case of steam turbine and lubricating oils where it is highly desirable for the oil to separate rapidly from any steam or water which may reach it. Thus, a desirable characteristic of steam turbine and lubricating oils is good demulsibility, the ability to separate from water.

There are several methods of determining the ability of an oil to separate from water. One of these is the ASTM test method in which steam is condensed in an oil sample to ascertain the time in seconds required for a given amount of oil to separate from the condensed steam. The time in seconds is known as the Steam Emulsion, or SE number of the oil.

SULFUR CONTENT

Free sulfur and sulfur compounds may be either desirable or undesirable ingredients in a petroleum product, depending upon the use for which the product is intended. They are desirable in certain lubricating and cutting oils because free sulfur or sulfur compounds increase film strength. However, lubricating oils containing free sulfur cannot be used where copper, brass, or other nonferrous metals are present because free sulfur is corrosive to these metals.

Similarly, free sulfur and corrosive sulfur compounds are undesirable in gasoline and diesel fuel because, when these products are burned, the sulfur is converted into compounds, such as sulfur dioxide. These compounds may mix with water, another product of combustion, to form sulfurous or sulfuric acid—both of which are highly corrosive to ferrous engine parts. Furthermore, free sulfur and corrosive sulfur compounds have a corrosive effect on brass fuel lines, carburetor parts, and the like.

The presence of free and corrosive sulfur in gasoline and kerosine is usually determined by the copper strip test method. This method involves determination of discoloration produced when a strip of sheet copper is immersed in the product for three hours at a temperature of 122° F. A similar method, using a temperature of 212° F is used for determining the corrosive properties of lubricating oil. If, at the end of the three hours, the copper strip shows no signs of discoloration, the corrosion test is reported as negative. If the copper strip is discolored, the sample is reported as corrosive.

VAPOR PRESSURE (REID)

All liquids tend to vaporize as a result of a positive pressure exerted by the liquid. When a liquid is placed in a suitable container and the temperature controlled, an accurate measure of the pressure exerted by the vaporized liquid may be obtained. This vapor pressure indicates the tendency of a liquid to vaporize. Vapor pressure—and hence vaporization—increases with increased temperature of both the product and the surrounding atmosphere. Vapor pressure is also dependent on the composition of the liquid.

Vapor pressure is an important factor in all gasoline—both from the standpoint of safety in handling and from the standpoint of performance. In internal combustion engines, the fuel must vaporize into the cylinder, through the carburetor and into the manifold. If the vapor pressure is too high the fuel will vaporize in the fuel pump and feed lines, causing vapor lock. If the vapor pressure is too low, the fuel will not vaporize rapidly enough, resulting in uneven operation.

Although many test methods have been developed for determining vapor pressure, the one most commonly used with petroleum products is the Reid Method. This standard test method is used to determine the vapor pressure of volatile, nonviscous petroleum products.

The Reid Method employs a metal cylinder or bomb, having two chambers (one for liquid and one for air) which are connected by control valves. (See fig. 7-2.) The bomb is fitted with a pressure gage and is constructed to withstand pressure. The product to be tested is placed in the liquid chamber, and the bomb is agitated and immersed in a water bath at 100° F.

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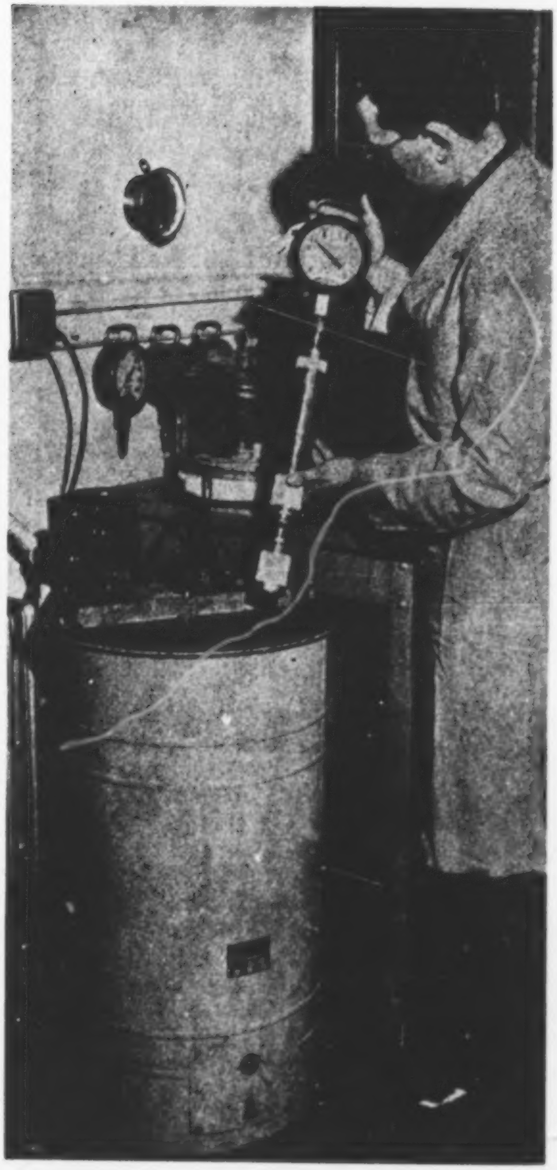

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Figure 7-2.—Apparatus used in Reid Vapor Pressure method.

This process is repeated and pressure gage readings taken at intervals. These readings are averaged to obtain the uncorrected pressure which is then converted to Reid Vapor Pressure by the use of an ASTM table. Reid Vapor Pressure is usually expressed as pounds per square inch (psi), but may also be expressed either in terms of millimeters of mercury or atmospheres.

DISTILLATION

The process of distillation is commonly used in the laboratory to test various petroleum products—particularly those which are vaporized in the course of their use, as are gasoline, kerosine, and solvents. By means of laboratory distillation tests, the distillation range of a given product is determined, as well as the amount of the product vaporized at various temperatures.

Knowledge of distillation range aids in predicting performance characteristics. Gasoline must be sufficiently volatile to permit easy starting of an engine without preheating; it should not be so volatile that excessive evaporation losses occur or that premature vaporization in carburetors or fuel lines takes place, resulting in vapor lock. In the case of kerosine which is to be used for illuminating purposes, the presence of excessively high boiling point fractions results in the clogging or encrusting of lamp wicks. In the case of solvents, distillation figures indicate the solvency value of the products, and in the case of solvents used in paints, indicate drying time.

There are many possible variations in the details of distillation test methods, but all test methods involve the general procedure of vaporizing the liquid, under specific conditions, and recording the results. The apparatus approved by the ASTM for the distillation test is shown in figure 7-3. A sample of the product being tested is heated in a flask—known as an Engler flask—which is fitted with a thermometer. The vaporized portions of the product pass through a brass tube condenser which extends through an ice-water bath into a glass cylinder. The results are expressed in a number of figures which generally include: (1) initial boiling point, which is the temperature at which the first drop of distillate falls from the end of the condenser tube; (2) final boiling point (also called end point), which is the temperature at which the last bit of the product is vaporized; and (3) temperatures at which the various fractions are distilled.

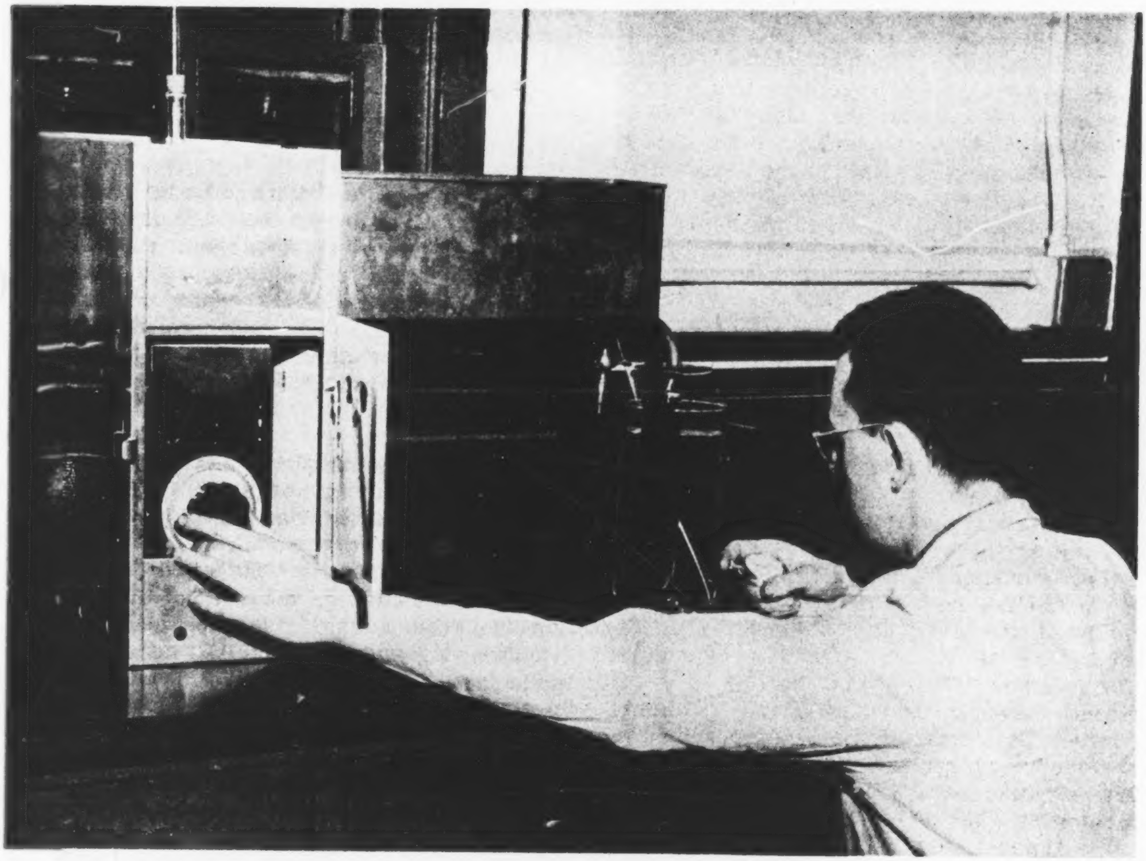

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Figure 7-3.—Approved ASTM apparatus for distillation test.

KNOCK CHARACTERISTICS OF GASOLINES

The occurrence of knock, when using motor or aviation gasolines, is caused by an excessively rapid combustion of the last portion of the burning charge. The knock characteristics of automotive gasolines and of aviation gasolines having a rating below 100 are normally expressed in terms of octane number. The knock characteristics of aviation gasolines having a rating above 100 are normally expressed in terms of performance number.

Scales for rating the knock performance characteristics of gasolines, as well as test methods for determining these characteristics, have been developed over a period of about thirty years. As early as 1921, a Cooperative Fuel Research Steering Committee, known as the CFR Committee, was formed to represent such groups as the Society of Automotive Engineers, American Petroleum Institute, National Bureau of Standards, and the Automotive Manufacturers' Association. A subcommittee of the CFR Committee developed the first standardized test method for determining knock characteristics of gasoline and this method was subsequently approved by the Society of Automotive Engineers and the ASTM. The present octane number scale was approved by the CFR Steering Committee in 1930. However, with the advent of gasoline components rating above 100 octane number, a system of extending the knock rating scale above 100 was required. The performance number scale, adopted by the Army and Navy during World War II, has gained the widest acceptance.

With the development of new high-speed engines and gasolines suitable for their operation, new test methods have been and are being designed for determining the knock performance characteristics of these gasolines. Test methods of determining knock characteristics of gasoline are discussed in the following pages, according to the type of gasoline to be tested, namely: automotive gasoline, and aviation gasoline.

Automotive Gasolines

Two methods are used to determine the knock characteristics of automotive gasolines: Motor Method and Research Method. Results of both methods are reported as octane number. Although the Motor and Research ratings of some gasolines are nearly the same, those of other gasolines differ materially. It is for this reason that the method used must be reported with the results of the test, as "80 octane number, Research Method" or "80 octane number, Motor Method." The word number should be included. Reference to "100 octane" gasoline is incorrect as "octane" is a hydrocarbon and therefore has no real meaning in this connection. "Octane number," on the other hand, clearly indicates a rating scale.

The Motor Method indicates the knock characteristics of the gasoline under severe conditions—that is, at high temperatures and speed. In order to determine more accurately the kock performance characteristics of motor gasolines under mild conditions—that is at temperatures and speed more nearly approximating ordinary driving conditions, the Research Method was developed. The latter method, developed by CFR in 1939 and standardized by ASTM in 1950, is now most commonly used. The two methods are described briefly below:

Motor Method.—The ASTM octane number, Motor Method, is determined by comparing the knock tendency of the fuel in question with a reference fuel of known octane number, when both are used in a test engine under controlled conditions. The engine used for testing motor fuels is known as the ASTM-CFR engine. It is a single-cylinder internal combustion engine which operates under specified conditions of intake air, mixture, and cylinder jacket temperatures, speed, compression ratio, spark advance, humidity, fuel-air ratio, and other factors.

Reference fuels are obtained by mixing different percentages of pure iso-octane (which has been given an arbitrary knock rating of 100) and normal heptane (which has been given an aribtrary knock value of 0). The octane number of the fuel in question is the percentage by volume of iso-octane in the reference fuel which matches the knock characteristics of the fuel when compared by this method.

Research Method.—In this method, also, the knock tendency of the fuel in question is compared with that of a reference fuel of iso-octane and normal heptane. The Research Method employs the same engine as that used in the Motor Method, but different operating conditions are specified. For example, the Research Method calls for the operation of the ASTM-CFR engine at 600 rpm and a constant spark advance, whereas the Motor Method specifies 900 rpm and a variable spark advance. Other changes include no heating of the intake mixture and different relation of compression ratio to octane number.

The difference between the octane number ratings of a fuel by Research and by Motor methods, which results from its response to this increase in severity of operating conditions, is called the "sensitivity" of the fuel. Some fuels have little or no sensitivity. Other components have negative sensitivity—that is, the Motor rating is higher than the Research.

Aviation Gasolines

Aviation gasolines differ from motor gasolines mainly in volatility and antiknock value. Knock ratings of aviation gasolines are determined at both lean and rich-mixture operating conditions. The methods for determining the knock performance characteristics of aviation gasolines under each of these conditions are: Aviation Method which determines the knock characteristics at a lean fuel-air ratio (the results of which are called either the lean or cruise rating); and the Supercharge Method which determines the knock characteristics under supercharge rich-mixture conditions (the results of which are called the rich-mixture rating). Reference fuels (normal heptane, iso-octane, and iso-octane plus tetraethyl lead), by definition, have the same ratings by Aviation and by Supercharge methods. Most aviation gasolines differ materially in rating between the two methods because of sensitivity, (although some components have zero or negative sensitivity—that is, aviation rating equal to or higher than Supercharge rating).

In specifying ratings of aviation gasolines, it is common practice to give the lean rating first and to follow this by the rich-mixture rating. Thus, an aviation gasoline designated 115/145 has a performance number of 115 when the Aviation Method is used and 145 when the Supercharge Method is used.

The Aviation Method was established about 1936. Development of the Supercharge Method was started about 1940, to measure the knock performance characteristics in rich-mixture take-offs.

The Aviation and Supercharge methods are described briefly below:

Aviation Method.—By operational conditions, this method is restricted to testing gasolines of 70 aviation octane number and over. An ASTM-CFR engine, basically similar to that employed for motor gasoline knock ratings, but differing in details, is used for rating fuels by the Aviation Method. Determination of the knock performance characteristics is made by comparing the average temperature of a thermal plug in the combustion chamber of the engine for the fuel in question with the averages for blends of reference fuels of known octane number.

As previously mentioned, the knock characteristics of aviation gasolines having a rating below 100 are normally reported in terms of octane number. In determining aviation octane number up to 100, the reference fuel is a blend of iso-octane and normal heptane. As in the case of automotive gasolines, the aviation octane number of the fuel in question is the percentage by volume of iso-octane in the reference fuel which matches the knock characteristics of the fuel when compared by this method.

In determining the knock characteristics of aviation gasolines having a rating over 100 octane number, the reference fuel used is iso-octane with additions of tetraethyl lead. In this case, the knock characteristics are reported in terms of performance number. (They may also be reported as iso-octane plus tetraethyl lead.) Aviation octane ratings below 100 may be converted to performance number by the use of tables. The relationship of these rating scales is shown in figure 7-4.

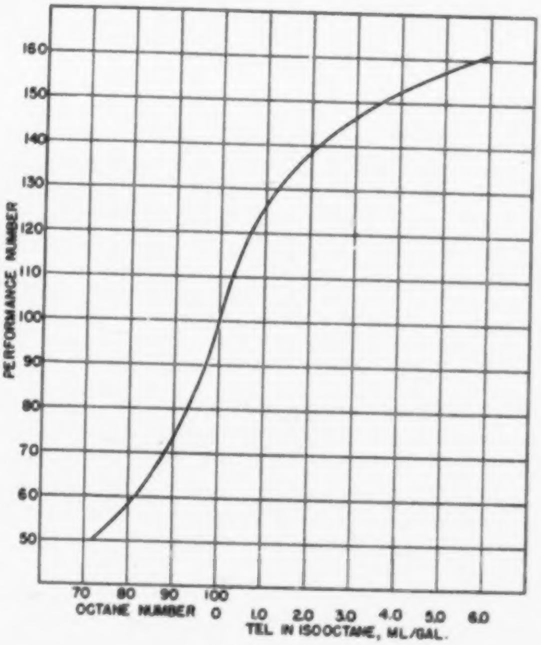

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Figure 7-4.—Relationship of octane rating and performance number scales.

Supercharge Method.—By operational conditions this method is restricted to testing fuels of 85 supercharge octane number and over. In this method, as in the aviation method, an ASTM-CFR engine basically similar to those of the foregoing methods but differing substantially in many details is used. The knock performance characteristics of the gasoline in question are determined by comparing the knock-limited power developed by the fuel in question with those for blends of reference fuels. The ratings are reported in the same way as are those obtained by the Aviation Method. A comparison of the ratings obtained by the Aviation Method (lean rating) and the Supercharge Method (rich-mixture rating) is shown in figure 7-5.

CETANE NUMBER

Cetane number is the measure of the ignition quality of diesel engine fuels. When diesel fuel is injected into the combustion chamber of a diesel engine, ignition does not occur immediately. The interval between injection and ignition is known as the ignition delay. If this

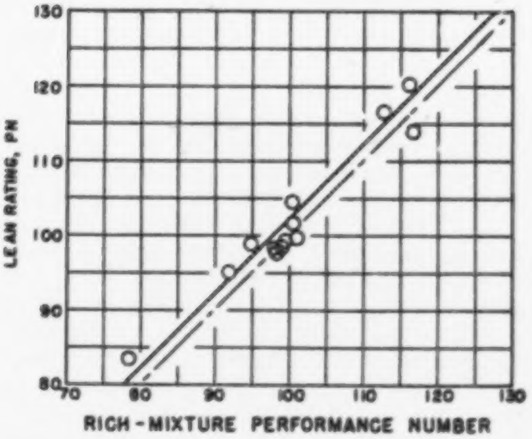

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Figure 7-5.—Relationship of lean and rich-mixture ratings of aviation gasolines.

delay is relatively long, the accumulated fuel burns with great rapidity causing engine roughness or knock. A short ignition delay is characteristic of fuels of high cetane number.

As in determining the octane number of gasolines, the diesel fuel to be tested is compared with a reference fuel of known cetane number, when both are used in a test engine under controlled conditions. The reference fuel for determining cetane number is a mixture of cetane (which has been given an arbitrary ignition quality rating of 100) and alpha-methyl-naphthalene (which has been given an arbitrary ignition quality rating of 0). The cetane number of the fuel in question is the percentage by volume of normal cetane in the reference fuel which matches the ignition quality of the fuel when compared by this method.

The cetane number of diesel fuels is significant for engine starting and smoothness of operation. Smoke and exhaust odor vary to some extent with cetane number. However, the cetane requirements of individual diesel engines vary and cannot be defined sharply because of differences in engine design and service. Whereas fuels having high cetane numbers (above 50) are desirable for use in high-speed diesel engines, many large, slow-speed diesel engines operate satisfactorily on fuels having a cetane rating as low as 30.

THERMAL VALUE OF FUEL OILS

The thermal (calorific) value of fuel oil is the amount of heat produced as a result of its complete combustion and is expressed in calories or Btu's (British Thermal Units). A calorie is the amount of heat necessary to raise the temperature of one gram of water one degree Centigrade. The British Thermal Unit is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. One Btu is equal to 252 calories. One calorie per gram is equal to 1.8 Btu's per pound.

A knowledge of the thermal value of fuel oil is necessary in determining the efficiency of oil-burning equipment, and may also be useful in choosing between oils which are equally satisfactory for a specific purpose.

To determine the thermal value of a fuel oil, a sample of the oil to be tested is placed in a bomb, which, in turn, is placed in a waterjacketed calorimeter. The sample is ignited and the rise in water temperature measured. The gross thermal value is the figure obtained by dividing the temperature rise of the water by the weight of the sample. To determine the net thermal value, certain corrections are made. It should be noted that the net thermal value may be 1000 Btu's lower than the gross thermal value.

In general, it may be said that the thermal value per unit of weight increases as the API gravity increases. For example, an oil of 10 API gravity may show 18,270 Btu's per pound, while an oil of 20 API gravity may show 18,850 Btu's per pound. However, the reverse is true when the quantities are measured in terms of volume. For example, the 10-gravity oil may show 152,120 Btu's per gallon, and the 20-gravity oil 146,580 Btu's per gallon.

NEUTRALIZATION AND SAPONIFICATION NUMBERS

The neutralization number (commonly called neut number) of a lubricant is the number of milligrams of potassium hydroxide (an alkali) required to neutralize one gram of the sample. Thus, the neut number indicates the acidity of a product. The neutralization number of the usual well-refined oil normally ranges from 0.02 to 0.10 or even slightly higher. These low values indicate adequate removal of acidic materials used in refining the oil. In the case of used oil, the neutralization number is useful as an indication of the amount of organic acids formed in the oil during use.

The saponification number applies only to compounded oils (petroleum oils to which some animal or vegetable oil, or other chemical substances have been added). This number, frequently called the sap number, is the number of milligrams of potassium hydroxide required to saponify one gram of the oil. (Saponification involves the decomposition of a fat or ester by an alkali to form a mixture which is the base of soap.) This number indicates the presence and percentages of fatty oil compounds in a lubricant.

Both the neutralization number and the saponification number are also used to determine the amount of fats or fatty oils in soaps which are used as ingredients of grease.

COLOR

The color of an oil is no indication of its quality but is an important consideration in refining oils for certain uses. For example, very pale oils are specified for medicinal oils and for textile machine lubricants. In the latter case, dark oils would cause stains if they came in contact with textiles. Color is also important in dry-cleaning solvents. Color is sometimes used in judging the amount of deterioration of a used lubricant—such judgment being based on a comparison of samples of used and unused oil.

Several instruments may be used to determine color, but ASTM recommends the ASTM Union Colorimeter for testing oils which are darker than pale-straw color. Most lubricants are included in this category. In this ASTM test method, a sample of oil is compared with a series of standard color disks until the nearest match is obtained. Colors are reported as numbers from 1 to 8, the higher numbers denoting the darker colors. This numbering system is designated as the ASTM color scale. If the color of an oil is darker than 8, a sample of the oil is mixed with kerosine 15 percent and 85 percent respectively, and the test is then reported as a dilute color. Thus, an oil, No. 7 dilute (color scale, ASTM) is darker than an oil, No. 8 (color scale, ASTM).

The Saybolt Chromometer is generally used for testing the color of gasolines, kerosines, and white oils. This test is performed by matching varying lengths of a column of oil against standard color disks. Saybolt color is reported from -16 to +30, the higher numbers denoting the lighter colors.

ASH CONTENT

The amount of noncombustible material (inorganic matter) in petroleum products is known as ash content. Clean lubricating oils should have no ash content, except that due to certain additives. The ash content of used lubricants is frequently determined to indicate the amount of dust or dirt which enters a crankcase through the carburetor air intake. In the case of heavy-duty oils containing certain additives, the ash content may be determined to indicate the amount of additive remaining in the oil.

In determining the ash content, a sample of oil is weighed in a small crucible and ignited over a burner until all combustible material has been removed. The residue left in the crucible is weighed, calculated to the percentage of the original oil, and recorded as the percentage of ash (ash content).

CARBON RESIDUE

All lubricating oils, when burned, leave deposits of carbon. Carbon-residue tests are indications of the amount of carbon which oils may be expected to deposit when subjected to high temperatures.

The Conradson Test Method is the carbon-residue test method most commonly used in the United States. In this method, a sample of oil is placed in a small crucible and heated in an apparatus approved by ASTM until all volatile portions of the oil are driven off. The residue is weighed, calculated to percentage of original oil, and reported as carbon residue.

OXIDATION TESTS

All oils deteriorate in service, primarily through chemical combination with other products. Since oil is always in contact with air during use, it combines most frequently with oxygen. Oil oxidation forms insoluble solid materials (sludge), and soluble materials (principally organic acids).

There are many methods for testing oxidation-resistance of various types of oils. One of the better known methods is the Sligh Oxidation test method. However, there is no one test method which is universally accurate for all types of oils. Thus, it is essential that the correct method be chosen to evaluate a given type of oil. Although many oxidation-resistance test methods have been developed, all are based on the same general procedure. Air or oxygen is brought into contact with the oil sample, which is kept at prescribed temperatures and other prescribed conditions for a specified period. Results are reported in one of the following ways: (1) amount of sludge and acid formed, (2) increase in oil viscosity, or (3) time required to produce a specified quantity of sludge or acid.

CORROSION

Petroleum products are mostly used in contact with metal, and when it is essential that the metal shall not be subjected to any corrosive action of a product, it is customary to require that the petroleum product pass an appropriate corrosion test. The corrosive substance most likely to be present in such products as gasoline and jet fuels is free sulfur which readily attacks copper. Products of this type are therefore required to pass a test involving contact with polished copper for a specified period of time, at a specified temperature. For certain other products, which may contain corrosive free acids, tests are required to determine the effect upon iron or steel as well as copper.

GUM IN GASOLINE AND JET FUELS

The behavior of a fuel in an engine and the length of time it may be stored without deterioration depend on the nature and amount of hydrocarbons in the fuel. As explained in chapter 3, hydrocarbons differ considerably in their tendency to combine with other materials, such as oxygen in the air. When the hydrocarbons in gasoline or jet fuels combine with oxygen, compounds which are insoluble in the fuel are formed. These compounds are called gums. Several test methods have been developed to determine either the amount of gum which will form if such a fuel is used immediately or the fuel to form gum in storage.

The ASTM Existent Gum in Fuels by Jet Evaporation Test Method (jet evaporation method) describes a procedure for determining the gum existent in motor gasoline and aircraft fuels at the time of the test. The results indicate the amount of gum deposition which may occur if the fuel is used immediately, but do not indicate the stability of the product toward gum formation in storage. In this test method, the existent gum in motor and aviation gasoline is determined by evaporating the sample to dryness under a stream of preheated air at approximately 320° F. In the case of jet fuels the existent gum is determined by evaporating the sample under a steam jet at approximately 450°. The existent gum is the amount of nonvolatile residue expressed as milligrams per 100 milliliters of sample, present in the fuel as received for the test.

The ASTM Oxidation Stability of Aviation Fuels (potential residue (gum) method) Test describes a procedure for determining the tendency of aviation fuels to form gum and deposits under accelerated aging conditions. The results may be used to indicate storage stability of the fuel.

Test methods such as these help refineries to learn how and why gum forms and to develop chemical activities which delay and limit the gum formed. Such additives are called gum inhibitors.

FREEZING POINT

The freezing point is an important characteristic of aviation fuels. The freeze point must be sufficiently low to avoid solidification and the blocking of filters at low operating temperatures. The freezing point test of aviation fuels is accomplished by cooling the fuel (freed of water) under specified conditions until hydrocarbon crystals appear. The freezing point is the temperature at which this occurs.

The specification for JP-4 jet fuel requires a freezing point of -76° F, and that for JP-5 a freezing point of -55° F. Therefore, JP-4 fuel is more suitable for prolonged high altitude flights or flights in polar regions. The freezing point of JP-5 fuels is normally adequate for all Navy flight operations.

WATER SEPAROMETER INDEX

The Water Separometer Index is used to determine the ability of jet fuels to release entrained or emulsified water when passed through a coalescer-type water separator under controlled conditions. It predicts the effectiveness of water separation from fuels by conventional filter separator operating at issue points.

THERMAL STABILITY OF JET FUELS

The Thermal Stability test is indicative of fuel performance during jet aircraft operation and is used to assess fuel stability at a given temperature. Unstable fuels deposit objectionable decomposition products in fuel system components of jet aircraft.

SMOKE POINT AND SMOKE VOLATILITY INDEX

The Smoke Point and Smoke Volatility Index indicate the burning characteristics of JP-4 and JP-5 jet fuels respectively, with respect to carbon formation within the combustors of jet engines.

PENETRATION

Penetration number indicates the consistency of greases, petrolatums, and similar plastic petroleum products. As explained in chapter 5, consistency of finished greases is affected primarily by the kind of soap used in their manufacture. It is also affected by the amount of soap, method of manufacture, water content, and rate of cooling. The penetration number is determined by grease makers to control uniformity in production and by users to compare greases. However, penetration number is not a true value of the ability of a grease to perform in service. To predict performance, other characteristics must be known.

In testing grease, an instrument known as a penetrometer, shown in figure 7-6, is used under prescribed conditions of temperature, load, and time. This instrument measures the depth to which a pointed cone penetrates the grease when the cone is dropped into a sample from a given height. The depth of penetration, in tenths of millimeters, is read on the scale of the penetrometer and reported as the penetration number. The lower the penetration number, the stiffer the grease; the higher the penetration number, the softer the grease.

DROPPING POINT OF GREASE

The ASTM dropping point of a grease is the temperature at which it passes from the semisolid to the liquid state under certain test conditions.

The ASTM dropping point indicates the resistance of greases to heat. The test method is

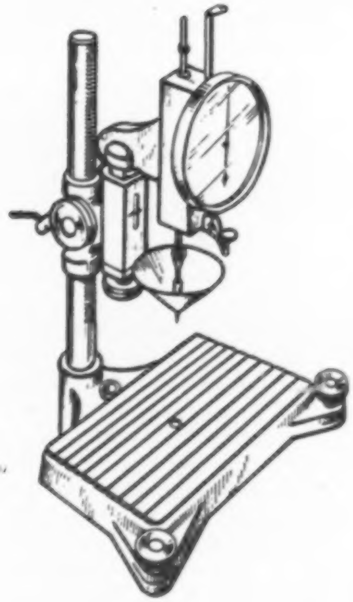

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Figure 7-6.—Penetrometer used in measuring consistency of greases.

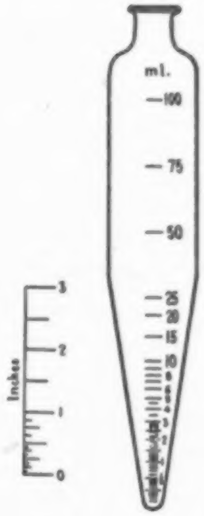

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Figure 7-7.—ASTM cone-shaped centrifuge tube.

used, for example, to distinguish conventional lime-base cup greases from high-melting-point types, such as soda-base greases.

SEDIMENT AND WATER (CENTRIFUGE METHOD)

The amount of water and insoluble solid impurities in petroleum products may be determined by several methods. The centrifuge method is considered by ASTM as the most desirable of the several methods. The apparatus used in this method is the ASTM cone-shaped centrifuge tube, shown in figure 7-7. In the centrifuge method, the oil to be tested is diluted with benzene and centrifuged under specified conditions. When this process is completed, the combined volume of water and sediment in the bottom of the tubes is read on each tube and recorded as the percentage of water and sediment, centrifuge method. This method for sediment and water is frequently referred to as BS & W (bottom sediment and water).

CHAPTER 8

MILITARY PETROLEUM PRODUCTS

Many specialized petroleum products must be developed by the military services to ensure adequate performance of complex and highly specialized military equipment. To develop these products, continuous research is necessary.

Research may be undertaken by any one of the military services in its own laboratories or may be performed by an outside agency under contract. In either case, the interested military service submits a description of the proposed research project to the Department of Defense, Office of the Director of Defense Research and Engineering. This description includes such information as the necessity for the research, results to be expected, estimated cost, and the number of persons required for performing the research.

The Office of the Director of Defense Research and Engineering, through its Committee on Fuels and Lubricants, coordinates research and development projects concerning petroleum for the three military services. This committee is made up of representatives of each of the military services and of industry. Proposed research projects, submitted by any of the military services, are reviewed by the full committee or by the appropriate panel to determine whether the project is worthwhile, whether it is a duplicate of other research, its cost, and the like. After these considerations, the proposal is either approved or rejected.

Since many petroleum products are utilized by the military services and the quality requirements of these products necessarily change with new developments in the equipment for which the products are designed, no attempt is made to cover all military petroleum products in this chapter nor describe single specifications.

Reference to chapter 7 "Testing Petroleum Products," will be helpful in understanding the discussion of products since quality requirements are normally described in terms of standard test methods. A review of chapter 3, "Properties of Crude Petroleum," which covers some of the chemical properties of hydrocarbons, will also be helpful.

MILITARY SPECIFICATIONS

Specifications for all military petroleum products govern the quality requirements of products used by the military services. The quality of products is dictated by the equipment and the anticipated conditions of service or operation. Quality is always tempered by availability. Availability is an important consideration in establishing specifications, even during peacetime, because the equipment must use the material which would be available in sufficient quantity during emergencies when petroleum becomes a critical item. Therefore, the aim of the Department of Defense is to ask for petroleum products of the quality consistent with requirements in military operation and with adequate supply.

The military services require an ever-increasing number of specialized types of equipment, each of which makes more complex the problem of supplying petroleum products. Recognizing this problem, the Department of Defense continuously attempts to combine the different requirements into joint specifications, and cancels those specifications no longer required. A reduction in the number of products required simplifies the refining problems for industry and the logistics problems for the services.

Specifications are documents, intended primarily for use in procurement, which are clear, accurate descriptions of the technical requirements for items, materials, or services, including the procedures by which it will be determined that the requirements have been met. Military specifications covering petroleum

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products, as well as other commodities, are divided into six sections, viz:

1. Scope.—Includes statement as to the product covered and classification or grade(s).
2. Applicable Documents.—Includes reference to other specifications, standards, or publications containing requirements pertinent to the product which must be met.
3. Requirements.—Briefly defines the product and specifies physical and chemical properties.
4. Quality Assurance.--Specifies inspection, testing, acceptance, and qualification requirements.
5. Preparation for Delivery.—Specifies appropriate packaging and packing requirements, markings, and other information relating to shipment requirements.
6. Notes.—Includes statement as to intended use, ordering data, standardization, whether or not qualification of the product or ingredients is required.

The procedure and format for preparation of specifications are described in the Defense Standardization Manual, M200.

Preparation of Specifications

The Office of the Assistant Secretary of Defense (Installations and Logistics) has the overall responsibility for coordination of the Defense Standardization Program. The military departments are assigned segments of the program, consistent with departmental capacity and supply interest, with due regard to departmental mission.

All specifications current in July 1955, were converted to either Federal or Military Specifications (MIL Series). New or reissued specifications are assigned to the military department having primary interest and are coordinated with other departments having user interest and with industry. The steps in establishing specifications are as follows:

1. A preparing activity of the Department of Defense prepares the specification in draft form.
2. The preparing activity circulates the draft for comment of other military departments, other government agencies, and sometimes private industry.
3. The preparing activity resolves comments, coordinates requirements, and circulates the final draft of the specification.
4. The preparing activity reconciles comments on the final draft, approves the document, and arranges for printing.

The Defense Standardization Manual provides for the issuance of interim (uncoordinated) specifications of the Navy, Army, and Air Force when, in an emergency, it is necessary to obtain specifications for immediate procurement. However, these uncoordinated specifications must be resolved as MIL Specifications after being in use 6 months.

Specifications are never static because requirements for military petroleum products necessarily change with new developments in military equipment and with changing operational conditions. Also, as standardization of Military Specifications progresses, uncoordinated specifications are superseded by coordinated specifications. Therefore, no attempt is made to describe herein any single specification, nor to list the specifications in effect at any given time.

MILITARY QUALIFIED PRODUCTS

Since most petroleum specifications covering lubricants and specialty items are based on performance requirements, extensive use is made of the Qualified Products List procedure. This procedure is utilized to avoid delay in procurement of items which require extensive testing under simulated or actual use conditions or prolonged time periods. A representative sample of the desired product is pretested for compliance with the specification requirements and the supplier's name placed on the Qualified Products List. In such cases, only inspection tests required under the specification are conducted on each individual batch. The qualification granted remains in force until the supplier changes formulation or ingredients, in which case new samples are submitted for qualification.

Authority is delegated to the military departments to prepare, issue, maintain, and cancel Qualified Product Lists. Qualification is appropriate under any of the following conditions:

1. The time required for testing in connection with production would unduly delay delivery of the products being purchased.
2. The tests would require special equipment not commonly available.
3. The costs of repetitive testing would be excessive.
4. The interests of the Government require assurance, prior to contract award, that the product is satisfactory for its intended use.

Summary of Qualification Procedures

As soon as practicable after a manufacturer requests qualification of a petroleum product, and if the request is approved, the activity concerned authorizes the test and sends the manufacturer necessary information including the military specification title and symbol, the instructions for forwarding the manufacturer's samples, and a statement as to payment of costs of tests. (Charges are made for qualification tests except where it is in the best interest of the Government not to charge for the test, as in cases where either adequate competition has not been developed in industry or sufficient sources of supply to assure availability have not been established.)

After the manufacturer has submitted samples and certification as required, tests are conducted at the laboratory designated by the activity responsible for qualification. A manufacturer's representative may be permitted to observe the testing in accordance with specified rules.

Upon receipt of results of the laboratory test, the activity responsible for qualification analyzes the results to determine whether the product is qualified. If approved, the product is listed in the Qualified Products List and the manufacturer notified. However, the manufacturer is also warned that the listing does not:

1. Guarantee acceptance of the product in any future purchase;
2. Constitute a waiver of the requirements of the specification as to acceptance, inspection, testing, or other provisions of any contract involving the product;
3. Permit any statements of approval to be reproduced, circulated, referred to, or otherwise used for private commercial sales, promotional, or advertising purposes.

If the product is not approved for inclusion in a Qualified Products List, the manufacturer is notified and a report covering the results of the test forwarded to him.

AVIATION GASOLINES

Gasoline is used as the fuel in all reciprocating aircraft engines. A reciprocating aircraft engine is one type of internal combustion engine. In order to operate, any internal combustion engine must have pistons, cylinders, a fuel, and a source of ignition. These factors, when properly coordinated, transmit the motion of the piston (inside the cylinder) to the circular motion of a crank shaft. The motion of the piston is caused by the expansion of the burning fuel. As shown in figure 8-1, the air fuel mixture is ignited in the combustion chamber by the spark plugs and burned as the piston travels toward top center. The ignited charge then expands and drives the piston downward in the cylinder barrel.

Properties of Aviation Gasolines

The most important properties of aviation gasolines are: (1) volatility; (2) knock value; (3) vapor pressure; (4) stability; and (5) solvent or corrosion properties.

1. Volatility.—A volatile liquid is one capable of readily changing from the liquid to the vapor stage by the application of heat or by contact with a gas into which it can evaporate. A fuel, to be useful in producing power, must be changed from liquid to vapor by the time the spark passes into the cylinder. Any portion of the fuel which fails to evaporate is not only wasted but may damage the engine by removing lubricating oil from the cylinder walls, piston rings, and other parts.

Isopentane, a component of all high grade aviation gasolines, is the most readily vaporized constituent of these fuels. It boils at 82° F and will form an explosive mixture, suitable for burning in an engine, when it is sprayed into air having a temperature of 65° F. In contrast, the least readily vaporized constituents form suitable mixtures in an engine only when they are sprayed into air having a temperature of 80° F or above.

Aviation gasoline is a mixture of components boiling over a wide range of temperature (82° F to 300° F). The boiling range of any given aviation gasoline is determined by laboratory distillation tests as explained in chapter 7. The distillation test provides a considerable amount of information concerning relative engine behavior. The temperature at which 10 percent of the gasoline is boiled off gives a reasonable prediction of the lowest atmospheric temperature at which the engine will start when primed with this gasoline (provided that the lubricating oil condition will permit the engine to turn over fast enough). The temperature at which 50 percent is boiled off indicates the ease with which the engine warms up. The temperature at which 90 percent boils off gives an indication of the

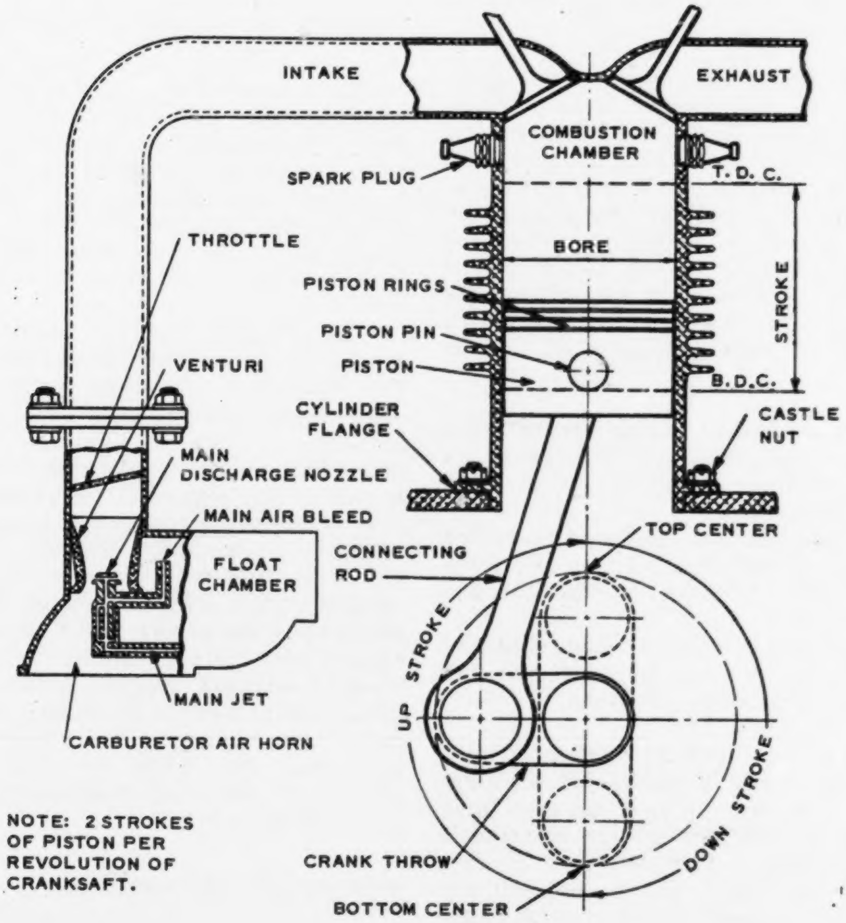
INTAKE
EXHAUST
COMBUSTION CHAMBER
SPARK PLUG
T. D. C.
THROTTLE
BORE
STROKE
PISTON RINGS
PISTON PIN
VENTURI
PISTON
B. D. C.
CYLINDER FLANGE
CASTLE NUT
MAIN DISCHARGE NOZZLE
MAIN AIR BLEED
TOP CENTER
FLOAT CHAMBER
CONNECTING ROD
UP STROKE
MAIN JET
CARBURETOR AIR HORN
DOWN STROKE
NOTE: 2 STROKES OF PISTON PER REVOLUTION OF CRANKSAFT.
CRANK THROW
BOTTOM CENTER

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Figure 8-1.—Diagram showing cylinder of an internal combustion engine.

possibility that some gasoline may not burn, resulting in damage to the engine as previously noted.

2. Knock Value.—In a spark ignition engine, the fuel, ignited in the combustion chamber, burns smoothly until part of it is consumed, but if either the fuel or engine operating conditions are unsuitable, the last remaining portion of the fuel burns with a suddenness resulting in a knock or ping. This sudden burning is called knocking or detonation. (The methods of determining knock characteristics of aviation gasolines have been described briefly in the previous chapter.)

Detonation has destructive effects both on engine parts and on performance. It increases the temperature of the combustion chamber, thereby reducing the ability of the lubricating oil to lubricate the cylinder walls and rings, and it unnecessarily weakens internal engine parts. Violent detonation also reduces power output.

The addition of tetraethyl lead decreases the knock tendency of gasolines. Tetraethyl lead, if added alone, would burn to lead oxide (a solid having a very high boiling point) and this would remain primarily in the cylinders. Therefore, a gasoline-soluble bromine compound is added to the lead to serve as a scavenging agent. As a result, lead bromide is formed on combustion. Lead bromide, having a much lower boiling point than lead oxide, is expelled from the combustion chamber with the exhaust gas.

3. Vapor Pressure.—As explained in chapter 7, the tendency of gasoline to vaporize is determined by the Reid Vapor Pressure Test method and is an index of the volatility of the liquid from which the vapor is produced. If the vapor pressure is too high, the fuel may vaporize in the fuel distribution system, causing vapor lock and possible stoppage of the engine. Conversely if the vapor pressure is too low, it will not vaporize rapidly enough with the result that engines are more difficult to start and operation may be uneven.

4. Stability.—Stability is that property of a gasoline which gives it the ability to retain its physical and chemical properties intact, even during extended storage.

Unstable gasolines lose the properties which provide full power and clean burning, and which prevent undesirable combustion chamber and carburetor deposits.

Military specifications and constant testing and inspection provide safeguards against the delivery or use of unstable gasolines.

5. Solvent or Corrosion Properties.—These properties are largely a function of chemical composition. An aviation gasoline containing such materials as sulfur and chlorine compounds and inorganic acids is destructive to the fuel system and to the engine. For this reason, the copper strip test is specified for aviation gasolines and a maximum sulfur content established.

Grades of Aviation Gasolines

Aviation gasolines utilized in military reciprocating engines include:

Grade
115/145
100/130
91/96
80/87

Grade 115/145 is most widely used by the military services. Lower octane grades are used in small fixed wing aircraft and certain helicopters, where available. Requirements of the individual grades are shown in table 8-1.

AUTOMOTIVE AND OTHER GASOLINES

Properties of Automotive Gasolines

The fuel system of an automotive engine is shown in figure 8-2. Automotive gasolines differ from aviation gasolines mainly in volatility and antiknock properties. They also differ in vapor pressure. Because of these differences, the use of automotive gasoline in aircraft is unsafe unless both the aircraft engine and the aircraft itself have been adapted for its use.

The volatility of motor gasoline, as a whole is slightly higher than that of aviation gasoline. The Reid Vapor Pressure of automotive gasolines is also usually higher than that of aviation gasoline. As we have seen in chapter 7, the knock characteristics of automotive and aviation gasolines are expressed somewhat differently and, therefore, quick comparison of this characteristic is somewhat difficult. However, one important difference which is related to knock characteristics can be pointed out. Aviation gasolines from grades 91/96 upward contain a higher lead content than automotive gasolines (thereby attaining superior antiknock performance). Moreover, if tetraethyl lead is used in automotive gasolines, both bromine and chlorine compounds are added as scavenging agents whereas in aviation gasolines only the bromine compound is added.

Military Automotive Gasolines

1. Combat.—Gasolines in this category are suitable for use in all automotive gasoline engines under all conditions of service. Two types of combat automotive gasolines are commonly used by the military services. Type I is intended for general use at all temperatures above 0° F; type II for areas where the mean temperature is consistently below 32° F. Chemical and physical requirements are shown in table 8-2.

2. Commercial Motor Gasoline.—This gasoline requires no special refining or processing other than that commonly employed for the commercial production of regular and premium motor gasoline used by the general public. Each grade has three automatic provisions for locality and climatic conditions.

Table 8-1.—Requirements of Various Grades of Aviation Gasolines

Grade	Color [1]	Tetraethyl lead content, ml/U.S. gallon, (max)[2]	Knock-rating (min)	
			Lean mixture	Rich mixture
80	Red	0.50	[3] 80.0	------
91/96	Blue	4.60	[3] 91.0	[3] 96.0
100/130	Green	4.60	[3] 100.0	[4] 130.0
115/145	Purple	4.60	[4] 115.0	[4] 145.0

[1] Color for each grade shall be within the minimum and maximum Air Force-Navy Aeronautical color standards for the applicable color. No dyes other than the following shall be present in the finished fuel:

Blue: Essentially an alkyl substituted anthraquinone;
Yellow: Essentially p-Dimethylaminoazobenzene;
Red: Essentially 2,3'-Dimethylazobenzene-4'-azo-2-naphthol

If the grade 80 fuel contains no tetraethyl lead, the color shall be no darker than plus 20 Saybolt.

[2] The tetraethyl lead shall be added in the form of an anti-knock mixture containing not less than 61 percent by weight of tetraethyl lead and sufficient ethylene dibromide to provide two bromine atoms per atom of lead. The balance shall contain no added ingredients other than kerosine, an approved inhibitor, and blue dye as specified herein.

[3] Octane number.

[4] Performance number. For rich-mixture knock ratings, this shall be determined at the fuel-air ratio at which the maximum indicated-mean-effective pressure of the lower bracketing reference fuel is obtained.

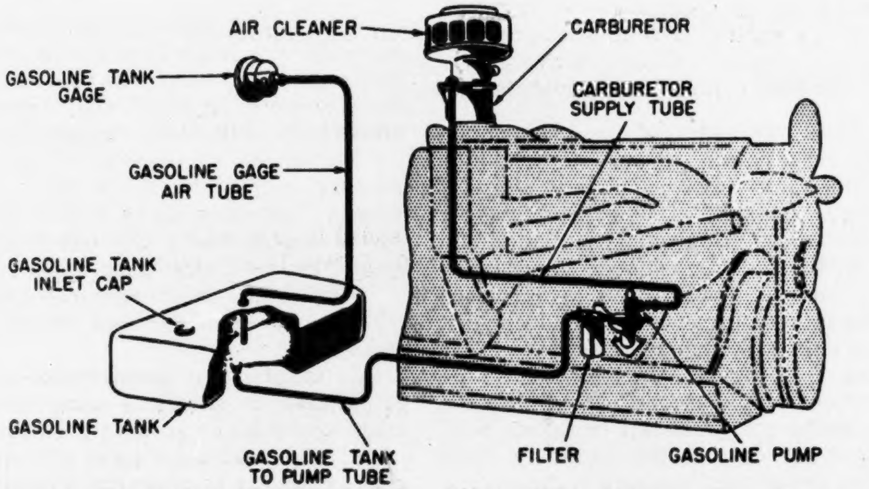
AIR CLEANER
CARBURETOR
GASOLINE TANK GAGE
CARBURETOR SUPPLY TUBE
GASOLINE GAGE AIR TUBE
GASOLINE TANK INLET CAP
GASOLINE TANK
GASOLINE TANK TO PUMP TUBE
FILTER
GASOLINE PUMP

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Figure 8-2.—Fuel system of an automotive engine.

Table 8-2.—Chemical and Physical Requirements of Automotive Gasolines (Combat) MIL-G-3056

	Type I	Type II
Distillation		
10 percent evaporation, °F	140-158	122 max.
50 percent evaporation, °F	194-239	203 max.
90 percent evaporation, °F	275-350	302 max.
Residue, percent, max	2	2
Reid vapor pressure, pounds	8 max.	14 max.
ASTM octane no., min	86/95	86/95
Gum, mg/100 ml., max	4	4
Sulfur, percent, max	0.25	0.25
Corrosion, max	1	1
TEL content, ml/gal., max	3.0	3.00
Oxidation stability, minutes, min.	480	480
Color	Red-Equal to standard	Red-Equal to standard

JET FUELS

Jet Aircraft Engines

Special fuels are required for jet aircraft engines. The jet aircraft engine, like the piston engine, produces power by the expansion of heated air. This engine consists of an air compressor (or compressors), a combustion section, and a turbine or turbines. Atmospheric air is taken in and compressed. Fuel, which is burned in the compressed air, expands through a turbine which in turn drives the compressor.

Two types of jet aircraft engines used by the military services are: (1) turbo jet, and (2) turbo prop. (The turbo jet is shown in figure 8-3.) These types differ only in the means by which they apply the power they produce to obtain propulsion of the aircraft. The turbo jet—which has been more widely used—produces thrust entirely by the jet; the turbo prop obtains thrust mostly from the propellor but also from the jet effect of the exhaust.

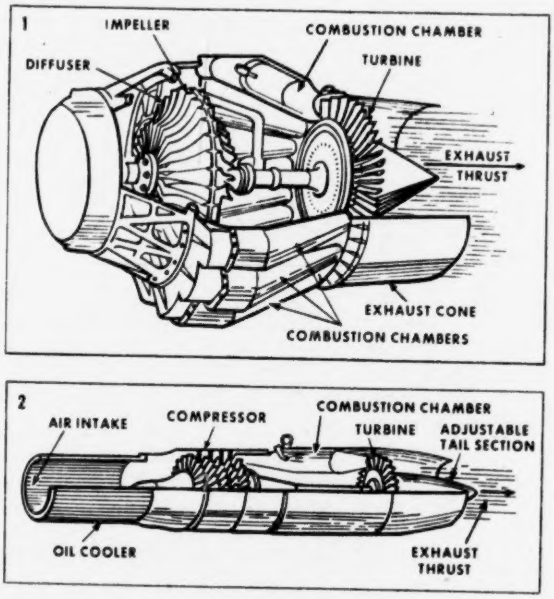

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Figure 8-3.—Turbo jet engines: (1) radial flow, (2) axial flow.

Property Requirements of Jet Fuels

Jet aircraft engine performance does not vary as much with fuel type as does piston engine performance. However, the belief, once held, that the jet aircraft engine would run on anything that would burn is no longer acceptable.

The major requirement of a fuel for any jet aircraft engine is that it be a source of heat energy. (This is also a major consideration in piston engine fuel.) For use in jet aircraft engines, the following properties are necessary:

1. The fuel must contain as much heat energy as possible both per unit weight and per unit volume.
2. Combustion properties—which are related both to chemical composition and volatility—must be as good as possible.
3. The fuel must have a low freezing point due to the low temperatures encountered by jet aircraft flying at high altitudes for long periods of time.

In addition, loss of fuel in flight by evaporation must be considered, as well as the fact that the fuel should be noncorrosive, should not clog fuel filters, and should not produce vapor lock or slugging. (Slugging is the loss of liquid fuel from tank vents owing to the pulling action of escaping vapors.)

Development of Jet Fuels

The gas turbine aircraft engine (turbo jet) was originally developed in Germany. It was further developed in Great Britain and was designed to use kerosine as the fuel. The U.S. jet engine was developed largely from the British design and a fuel (JP-1) was developed. This consisted principally of a well refined kerosine fraction from crude petroleum. JP-1, however, was more restrictive than the British fuel, requiring a flash point of 110° F (in comparison with the British requirement of 100° F) and a freezing point of -76° F (in comparison with the British requirement of -40° F). The availability of a kerosine fuel such as JP-1 became a major problem. Its availability was considered to be only about 3 percent of the average barrel of crude petroleum. Because of low potential availability, in comparison with gasoline fraction fuels, the military services developed an experimental fuel (JP-2), and subsequently, a fuel known as JP-3, which was supplied for operational aircraft. Because the fuel had a Reid Vapor Pressure ranging from 5.0 to 7.0 pounds per square inch, a percentage of the fuel in aircraft tanks was lost in flight, owing to the evaporation of light ends. The effective range of aircraft was accordingly decreased. To overcome this disadvantage, another fuel, known as JP-4, was developed. Effective 1 January 1952, all aircraft turbine and jet engine fuel purchased for the Navy and Air Force was to be JP-4. Subsequently, another kerosine type of jet fuel, JP-5, was developed for use by the Navy. It has a flash point of 140° F minimum, making it a safe fuel for storage on aircraft carriers. It has a freeze point of -55° F. It is the principal jet fuel used by the Navy. Thus, in a period of a few years, five types of jet fuels were developed by the U.S. military forces. It is to be expected that new types will be developed as research on jet aircraft engines progresses.

Types of Military Jet Fuels

Two types of jet fuels used by the military are:

1. JP-4, a wide cut, gasoline type fuel, has a low vapor pressure (2.0 - 3.0 psi, Reid), and was developed to overcome the problem of evaporation losses which were characteristic of JP-3.
2. JP-5, a high flash point, (140° F) kerosine type fuel which was originally developed for use by aircraft carrier planes where a safer fuel than JP-4 was required for storage aboard the carrier. The vapor pressure of JP-5 is normally zero. It is now the principal aircraft fuel used by the Navy ashore and afloat.

A summary of the important requirements of JP-4 and JP-5 is given in table 8-3.

Aviation gasoline has been used in military turbojet aircraft and therefore deserves mention at this point. Aviation gasoline can be used in some jet aircraft in an emergency, when different fuels for piston and turbine engines are not available in some particular area of operations. However, aviation gasoline should not normally be used in jet engines inasmuch as it reduces overall efficiency of operation and, if continuously used, necessitates increased operational maintenance.

FUEL OILS

In the following discussion, fuel oils are classified according to use as: (1) diesel fuels and (2) burner fuels.

Diesel Fuels

Diesel fuels are used in diesel engines in which air enters the engine at atmospheric pressure or is forced in under higher pressures by a pump or blower. The engine develops power by internal combustion in the same way as a gasoline engine, but differs in the way the fuel is ignited. In a gasoline engine, gasoline vapor is mixed with fresh air in a carburetor and ignited by an electric spark. In a diesel engine, fuel is injected into a combustion space through an injection nozzle which breaks the fuel up into a fine spray, and fuel vapor is then ignited by the heat of the air in the cylinder. The air obtains its heat as a result of being compressed by the piston. A diesel fuel-injection system is shown in figure 8-4.

The properties of fuel oils having considerable influence on the performance and reliability of a diesel engine are:

1. Ignition Quality.—The ignition quality of a fuel determines not only the ease of ignition and

Table 8-3.—Summary of Requirements of JP-4 and JP-5

	JP-4	JP-5
Flash point, min. °F		140.0
Reid Vapor Press., psi min.	2.0	
Reid Vapor Press., psi max.	3.0	
10% evaporated point, max. °F		400.0
90% evaporated point, max. °F	470.0	
End point, max. °F		550.0
Freezing point, max. °F	-76.0	55° F
Sulfur percent by wt. max.	0.40	0.40
Mercaptans, percent by wt. max.	0.0001	0.001
Inhibitors permitted[1]	Yes	No
Existent gum mg/100 ml. max.	7.0	7.0
Accelerated gum (16.0 hrs.) mg/100 ml. max.	14.0	14.0
Corrosion, copper strip, max.	1	1
Water separometer index, max.	55	85
Specific gravity (60/60) max.[2]	0.802	0.845
Specific gravity (60/60) min.[2]	0.751	0.788
Viscosity at -30° F centistokes, max.		16.5
Aromatics percent by vol. max.	25.0	25.0
Heating value (lower or net) Btu/lb. min.	18,400	18,300

[1] Inhibitors may be added to the extent required (max. 1.0 lb approved inhibitor for each 5000 U. S. gallons of finished fuel) to prevent formation of excessive gum during the oxygen bomb test. Several inhibitors are approved for use.

[2] Density of fuel at 60° F.

Density of water at 60° F.

of starting cold engines, but also the kind of combustion obtained from the fuel. The higher the cetane number, the easier the starting, even at low temperatures, together with quicker warm-up, smoother and quieter operation, lower maximum cylinder pressures and more efficient combustion.

2. Volatility.—In order to obtain low fuel consumption, low exhaust temperature, and minimum smoke, small diesel engines demand higher volatility than do heavier engines.

3. Tendency To Form Carbon Deposits on Engine Parts.

4. Viscosity.—Lubrication of the parts in the fuel injection system depends entirely upon the fuel oil, and therefore its viscosity cannot be below a certain minimum value.

5. Sulfur Content.

6. Ash and Sediment.

7. Flash Point.—A fuel having an excessively low flash point is dangerous in storage and handling.

8. Pour Point.—This is of particular importance for cold-starting an engine, and for handling the oil between the storage and the engine.

9. Acidity.—A fuel oil must not be corrosive. The military specification for marine diesel fuel oil provides for one grade. The Federal specification provides for four commercial grades: Arctic, Winter, Regular, and Heavy.

Some important chemical and physical requirements of the several grades of diesel fuels are shown in table 8-4.

Fuel Oil Burner (Military)

Fuel oil is burned in the furnaces of boilers to generate heat which is transferred to water, generating steam which serves to carry the heat energy to the engines for conversion into useful work. This work includes the propulsion of the ship, and the production of power for steering, lighting, ventilating, heating, cooking, refrigeration, operation of various types of electrical equipment, and the power for loading, aiming, and firing the ship's guns. The steam propulsion plant is, generally used in combatant ships of and above the destroyer class and in many of the smaller craft.

The military specification for burner fuel oil provides for two grades: (1) Navy Special which is intended for combatant vessels; and (2) Navy Heavy which is intended for other than combatant vessels. A comparison of the two grades may be

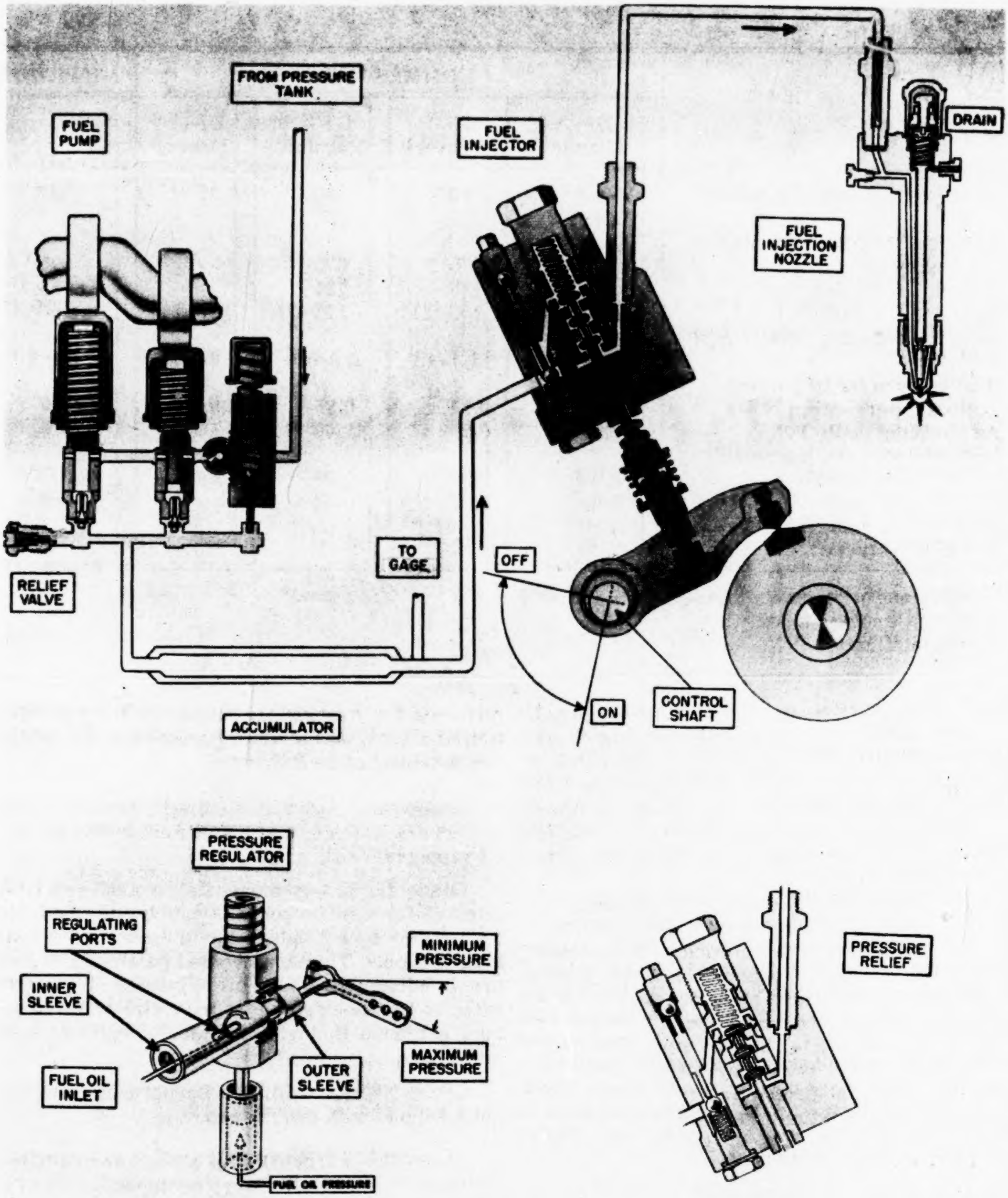
FROM PRESSURE TANK
FUEL PUMP
FUEL INJECTOR
DRAIN
FUEL INJECTION NOZZLE
RELIEF VALVE
TO GAGE
OFF
ON
CONTROL SHAFT
ACCUMULATOR
PRESSURE REGULATOR
REGULATING PORTS
MINIMUM PRESSURE
INNER SLEEVE
MAXIMUM PRESSURE
FUEL OIL INLET
OUTER SLEEVE
FUEL OIL PRESSURE
PRESSURE RELIEF

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Figure 8-4.—Diesel fuel-injection system.

Table 8-4.—Some Important Chemical and Physical Requirements of Commercial and Military Diesel Fuels

	COMMERCIAL				MILITARY
	DF-A (Arctic)	DF-1 (Winter)	DF-2 (Regular)	DF-4 (Heavy)	
Ignition quality, cetane number (min.)	40	40	40	35	47
Distillation, 90 percent point, ° F (max.)	550	575	675	--	675
End point, ° F (max.)	575	625	725	--	725
Flash point, ° F (min.)	100 (2)	100 (2)	125 (2)	130 (2)	150
Kinematic viscosity, centistokes at 100° F	1.4-4.0 (1)	1.4-4.0	1.8-6.0	5.8-20.6	2.1-6.0
Carbon residue on 10 percent bottoms, percent (max.)	0.12	0.15	0.25	0.50	0.20
Sulfur, percent (max.)	0.25	0.5	1.00	1.50	1.0
Water and sediment, percent (max.) (estimated)	0.03	0.05	0.05	0.50	0.01
Ash, percent (max.)	0.01	0.01	0.02	--	0.005
Cloud point ° F (max.)	-50	(3)	(3)	(3)	10
Pour point ° F (max.)	-70	(3)	(3)	(3)	0

(1) Equivalent to viscosity of 33-45 SSU at 100° F.
(2) Or legal requirement.
(3) See specification.

made by referring to table 8-5. Navy Special must be subjected to a compatibility test. This is necessitated by the fact that the Navy obtains its fuels on a worldwide basis and while two fuels might be stable by themselves and offer no problem as to sedimentation or fouling of heater surfaces, a mixture of the two fuels might be harmful.

The compatibility test is done by mixing the Burner Fuel Oil, Navy Special, under test in a 1 to 1 ratio with approved reference fuels, and then subjecting the mixture to thermal stability tests. It has been found that straight run fuels are compatible; cracked fuels which are in themselves stable are compatible; blends of cracked and straight run fuels may or may not be stable depending upon the properties of each blend. Standard reference fuels have been selected to represent: (1) the cracked type, and (2) the straight run type of fuel.

Fuel Oil Burner (Commercial)

Burner fuel oil is intended for use in oil-burning equipment for the generation of heat in furnaces for heating buildings, for the generation of steam, or for other purposes. Six grades are established as follows:

Grade No. 1.—A volatile distillate oil for use in burners which prepare fuel for burning solely by vaporization.

Grade No. 2.—A moderately volatile distillate oil for use in burners which prepare fuel for burning by a combination of vaporization and atomization. This is intended particularly for use in equipment where oil is burned in contact with, or in close proximity to, metal or refractory surfaces that are an integral part of the burner.

Grade No. 4.—An oil for burner installations not equipped with preheaters.

Grade No. 5 (Light).—An oil of intermediate viscosity for use in burners equipped with preheaters. However, preheating may or may not be required for this oil, depending on climate and equipment.

Table 8-5.—Chemical and Physical Requirements of Burner Fuel Oils (Military)

	Limits, grade	
	Special	Heavy
Flash point, closed cup (min.) ° F	150	150
Fire point (min.). ° F	200	200
Viscosity, at 122° F. (max.) SSF		150
Viscosity, at 122° F. (max.) SSU	225	--
Viscosity, at 85° F. (min.)	225	--
Ash (max.), percent	0.10	0.12
Water, by distillation (max.) percent	0.5	0.5
A.P.I. gravity (min.)	11.5	10.0
Pour point, upper (max.) ° F.	15	50
Carbon residue (max.), percent	15	--
Sediment by extraction (max.) percent	0.12	0.15
Water and sediment (max.), percent	0.5	--
Thermal stability (NBTL heater)	Pass	Pass
Explosiveness (max.), percent	50	50
Sulfur (max.)	3.50	--

Grade No. 5 (Heavy).—An oil similar to No. 5 (light) but of greater viscosity. Preheating may be required before burning this oil, and in cold climates preheating may be required before handling as well.

Grade No. 6.—A high viscosity oil for which preheating is always required before burning or handling.

KEROSINE

Kerosine is used by the military services as an illiminating oil, for space heating, and for general use. Kerosine should burn with a steady, clear flame in wick lamps. When used in stoves, it should vaporize completely but not to the extent that it will form explosive mixtures with air.

In refining kerosine, a fraction of crude which has a boiling range between 300° F and 530° F is used. Thus, there is an absence of heavy ends or extremely high boiling point fractions which interfere with clean burning in lamps or complete vaporization in stoves. Also, the absence of light ends or very low boiling point fractions gives the kerosine a relatively high flash point to secure safety in handling, storage, and burning. Viscosity is an important characteristic of kerosine because it controls the rate of feed through a wick. If too high, it feeds too slowly and the wick is charred; if too fast, consumption is high and smoke results.

Kerosine used by the military services must meet certain burning test requirements. The standard method of determining burning quality consists of observing the results obtained during and at the end of 24 hours' continuous burning of kerosine in a standard test lamp under controlled conditions. Specifications require that at the end of the test the flame shall not be smoky and shall be practically as large as when the final adjustment of the wick was made. Also, at the end of the test, the chimney of the lamp must be clear or only slightly clouded, and the wick shall have no appreciable hard incrustation.

The following physical and chemical requirements are specified for kerosine used by the military services:

1. Flash point, ° F. minimum 115
2. End point, ° F, maximum 572
3. Sulfur, percent, maximum. 0.13
4. Color, Saybolt number, minimum . . +16

LUBRICATING OILS

The primary purpose of any lubricant is to reduce friction, and thereby eliminate metal-to-metal contact. Lubricating oil provides a film which permits surfaces to glide over each other with less friction. Therefore, lubrication is essential to prevent wear in any mechanical device where there are surfaces rubbing against each other. The military services use many types of lubricating oils. The selection of the proper lubricating oil for a given application depends upon the design of the equipment and the conditions under which the equipment is to be operated.

Functions of Internal Combustion Engine Oils

In internal combustion engines, lubricating oils must perform four basic functions: (1) lubrication; (2) cooling; (3) cleaning; and (4) sealing.

1. Lubrication.—In order to lubricate properly, an oil must have the following characteristics:

a. It must be of low enough viscosity to flow readily between closely fitted, rapidly moving parts but of sufficient viscosity to prevent metal-to-metal contact between these parts.

b. It must be tough enough so that it will not break down or fail under high temperatures and pressures.

c. It must have a low enough pour point to enable it to flow readily when starting under extremely low temperatures.

d. It must have high enough flash and fire points so that it will not burn, vaporize, or otherwise be consumed under high heat.

e. Its carbon content must be low enough so that it will not deposit excessive amounts of carbon.

f. The oxygen absorption of the oil must be low enough so that varnish and gum do not form.

g. The neutralization number must be as low as possible. As explained in the previous chapter, a low neutralization number indicates that the amount of acid present is small. Small acid content is essential as acid is detrimental to engine parts.

2. Cooling.—A lubricant must cool moving parts by carrying off waste heat. This is especially true in aircraft engines where the lubricant must carry off approximately one-third of the total waste heat. In order to perform its cooling function, a lubricant must have sufficiently low viscosity to flow readily.

3. Cleaning.—Another major function of a lubricating oil is cleaning or carrying off dirt, road dust, small carbon and steel particles, gum, varnish, and the like. In recent years, this has become particularly important because of increased compression ratios, higher speed engines, high operating temperatures, and closer tolerances. Filters have been developed to filter out part of the dirt, and ventilation systems have been designed to carry off vapors and moisture. However, these devices perform only part of the job. Therefore, additives or detergents are blended with lubricating oils. The detergent, which is soluble in the oil, cleans dirt, gum, and other impurities from the engine and moving parts. It then holds these impurities in suspension. As the oil, carrying the particles in suspension, is circulated, the dirt is removed by the filter. However, gum and varnish are not removed by the filter. Consequently, the oil must be changed at intervals. If not, the amount of gum and varnish increases to the point where the oil can no longer hold them in suspension with the result that these substances are deposited throughout the engine, causing poor performance.

4. Sealing.—Another function of lubricating oil is to seal the space between piston rings, cylinder walls, and pistons to prevent blow-by (leakage of combustion gases from the combustion chamber, past the rings, into the crankcase). When the space between piston rings, cylinder walls, and pistons is properly sealed, the full force of the burning and expanding fuel gases is expended on the head of the piston, and none of the force is lost.

Engine Lubricating Oils

The following discussion of engine lubricating oils is presented according to the type of engine for which the oil is intended. However, mention should be made of a special type of oil which is used for both marine diesel engines and for automotive ground equipment. This oil, which is frequently called a heavy-duty oil, is generally an additive-type oil. An additive-type oil, as the name implies, is an oil to which chemical agents have been added in the refining process, to make it particularly suitable for its intended use. Additives may be broadly classed as pour point depressants, viscosity index improvers, extreme pressure agents, lubricity or oiliness agents, corrosion inhibitors, antifoam agents, and metal deactivators.

1. Marine Diesel Oils.—An additive-type lubricating oil is used for the lubrication of all types of marine diesel engines and for general use in diesel engines in shore establishments. Lubricating oil of this type which meets the military specifications is supplied in four different grades, corresponding to the following SAE viscosities: SAE 10 W, SAE 20, SAE 30, and SAE 50. The oil is required to be a stable, homogeneous blend or mixture of refined products and additives, such as detergency, antioxidation, antifoam, antiwear, anticorrosion, pour point depressing and viscosity enhancing agents, designed to improve the performance of the product. Other requirements are as follows:

a. The oil, even when contaminated with sea water, must be noncorrosive to all types of Navy bearing materials (including silver) and must not cause either excessive ring sticking or clogging of oil channels, and must keep cylinder and ring wear down to a minimum. The oil must be uniform in quality and must not be excessively degraded by approved mechanical fibrous types of filters, centrifugal purifiers, or by sea water contamination.

b. The oil must not cause excessive lacquer, carbon, or sludge deposits on any part of internal combustion engines when operated under either normal aspiration or snorkel conditions.

c. The oil must not produce excessive foaming in internal combustion engines or reverse gears. Foaming is caused by the mixing of air with the oil. When foaming occurs, less oil is present and consequently the proper oil film is not formed on the metal. In addition, quite frequently excessive foaming causes oil to be lost as a result of foaming over.

d. The addition of a new marine diesel lubricating oil to any other new or used lubricating oil conforming to the military specification must not cause sludging or otherwise affect the quality of the new or used oil, as indicated by engine performance.

e. Additive agents must remain uniformly distributed throughout the oil and all temperatures above the pour point and up to 250° F. When the oil is cooled below the pour point, it must regain homogeneity on standing at a temperature of not more than 10 degrees above the pour point of the oil.

In addition to standard tests such as viscosity, flash point, carbon residue, and the like, certain performance tests are required. Among these are engine tests, bearing corrosion tests, compatibility tests, and homogeneity tests.

2. Lubricating Oils For Automotive Ground Equipment.—The military specification for this type of oil prescribes that the oil shall be a petroleum or synthetically prepared product, or combination thereof. This oil is intended for the lubrication of internal combustion engines (except aircraft engines) or for general purpose lubrication. This oil is supplied in three viscosity grades (SAE 10, SAE 30, and SAE 50). The physical requirements of this oil are given in table 8-6.

3. Reciprocating Aircraft Engine Lubricating Oil.—The military specification for this type of oil requires that the oil be a qualified, highly refined straight mineral oil containing an ashless dispersant additive.

4. Lubricating Oils for Gas Turbine Aircraft Engines.—Two military specifications cover requirements for oils intended for use wherever jet engine oil is required. They are synthetic oils, differing mainly in viscosity and load carrying ability.

Steam Cylinder Oils

The type of oil required for the lubrication of steam cylinders is determined by: (1) steam temperature and pressure; (2) saturation; and (3) whether the steam is to be recovered for further processes.

Steam cylinder oils are usually residual, heavy-bodied oils. Paraffin and mixed base crudes are the most suitable for making these oils. Two types of steam cylinder oils are used extensively by the military services, particularly by the Navy. These are designated as (1) lubricating oil, mineral, cylinder; and (2) lubricating oil, compounded.

1. Lubricating Oil, Mineral, Cylinder.—This is a heavy mineral cylinder oil which must

Table 8-6.—Physical Requirements of Three Viscosity Grades of Oil for Automotive Ground Equipment

	Grade SAE 10	Grade SAE 30	Grade SAE 50
Kinematic viscosity			
Centistokes at 130° F	18.1 to less than 25.2	39.8 to less than 55.0	
Centistokes at 210° F			19.2 to less than 21.6.
Viscosity index, minimum	85	55	75.
Pour point, ° F., maximum	minus 10	0	15.
Stable pour point, ° F., maximum	minus 10		
Flash point, ° F., minimum	360	390	400.

consist of petroleum hydrocarbons free from additives other than a pour point depressant. Various grades of this oil are used for the lubrication of noncondensing steam engine cylinders.

2. Lubricating Oil, Compounded.—These oils are compounded with various fatty oils in specified percentages. Specifications require that additive agents, when approved for inclusion, must remain uniformly distributed throughout at all temperatures above the pour point and up to 250° F. If the oil is cooled below the pour point, it must regain homogeneity on standing at temperatures of 10° F above the pour point. Compounded lubricating oils are used in special applications, generally involving moisture or worm gears or wick feeds. They are used for cylinder and valve lubrication of reciprocating steam engines when condensate is not recovered.

Gear Lubricants

Many factors must be carefully considered in selecting a gear lubricant. Some factors are: the type of gears to be lubricated, the different operating speeds, temperatures, load conditions, and whether the oil is required to lubricate both gears and bearings. The principal qualities required of any gear lubricant are high V. I., proper viscosity, demulsibility, chemical and thermal stability, and freedom from foaming. Because modern gear systems generate considerable friction and carry high loads, many of them fail in a relatively short time if uncompounded mineral oils are used as lubricants. Therefore, various oiliness and extreme pressure agents are added to the mineral oils. Extreme pressure agents (frequently called EP agents) produce a nonscuffing film on the gears which increases the amount of load that can be carried.

One military specification calls for an oil to be used for lubricating aircraft gears at low temperatures. This oil comes in two grades, one for use under extreme low temperature conditions and the other for general use in aircraft gear mechanisms, exclusive of engines. This oil must be qualified, well-refined mineral oil having extreme pressure properties.

Another military specification covers one grade of lubricant suitable for universal gears at subzero temperatures. This specification requires powerful EP agents. This oil is intended for the lubrication of automotive gear units and heavy duty industrial type enclosed gear units (including hypoid gears, steering gears, and fluid lubricating universal joints of automotive equipment) operating under extreme pressure in temperatures consistently below 0° F.

General Purpose Lubricating Oils

High grade lubricating oils for other than specialized uses are covered by one military specification. This specification requires that general purpose lubricating oils shall be 100 percent mineral oil, free from additives except pour point depressants and antifoam agents. The specification provides for 11 grades of general purpose lubricating oils. The various grades are identified by military symbols, each symbol consisting of four digits. The viscosity requirements of each grade, and the corresponding SAE viscosities, are shown in table 8-7.

LUBRICATING GREASES

In general, grease should not be used where oil will perform the necessary lubrication. However, there are conditions under which grease is a more suitable lubricant. For example, grease is used in bearings which, because of their nature, are unable to retain oil. Grease is also used in inaccessible bearings where the grease is applied by grease cups. (Use of oil in such bearings, would necessitate shutting

Table 8-7.—Viscosity Requirements of Grades of General Purpose Lubricating Oils and Corresponding SAE Viscosities

Grade	Viscosity SSU at 130° F	SAE Viscosity
2075	70-90	SAE 10
2110	90-120	SAE 20W
2135	120-145	SAE 20
2190	185-205	SAE 30
2250	245-280	SAE 40
3042	40-44	SAE 10W
3050	45-55	SAE 20
3065	60-70	SAE 30
3080	75-90	SAE 40
3100	90-105	SAE 50
3120	115-125	SAE 60
3150	140-160	SAE 70

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down the machinery.) Also, under dirty atmospheric conditions, the use of grease is advisable as it seals the ends of the bearings and thus prevents dust and dirt from entering the bearings.

Property Requirements of Greases

The most important requirements of greases are:

1. Stability.—A grease must be stable both during storage and when in use. It must be free from bleeding (separation of oil), oxidation, and changes in consistency.
2. Noncorrosiveness.—The grease must not chemically attack the various metals and other materials with which it comes in contact.
3. Water Resistance.—In some cases, a grease which is insoluble in water is required. In others, the grease must be only resistant to the weathering or washing action of water.
4. Satisfactory Performance in Operation.—A grease must perform satisfactorily in the equipment for which it is intended or inadequate lubrication will result.

Various types of soaps are used in the manufacture of grease. Properties of greases vary with the type of soap used.

1. Lime-base grease is water resistant and has good pumpability. However, lime-base grease has a low melting point and therefore should be applied only where temperatures will not exceed 175° F.
2. Soda-base grease has a high melting point However, it is soluble in water.
3. Aluminum-base grease is water resistant. However, it has a comparatively low melting temperature, and it changes texture (becoming leathery) on heating and cooling.
4. Lithium-base grease is water resistant and has a wide range of operating temperatures.
5. Barium-base grease is also water resistant and has high heat stability.

There are a number of military specifications covering greases required for special military applications. Only seven of these are discussed here.

Bearing Grease for General Ordnance Use

The military specification for this type of grease requires a smooth lithium soap, general purpose grease. It must contain additives which provide corrosion inhibition and have a normal operating range of -20° F to 150° F. This grease is intended for use in the lubrication and protection against corrosion of plain, ball, and roller bearings, and for the preservation of threads on ammunition. The grease is required to be a homogeneous, water-repellent mixture of high-grade materials, free of any detrimental toxic or irritating effects, and must consist of petroleum oil, metallic soap, and necessary additives. The use of ingredients such as will stain the human skin in a semipermanent manner, or soften dried coatings of zinc chromate primer and synthetic-lacquer-resisting primer is undesirable.

Torque value—which is one of the properties to be tested—is determined on the grease test machine illustrated in figure 8-5. This machine is fitted with a test bearing at each end. Bearings are packed full of compound with the bearing loaded so that the grease is flush with both faces of the bearing. The shaft speed is 1750 rpm and the 1-hp driving motor is started across the line. Torque arm loads are read directly from the scale and converted to pound-inches from the lever arm. When the grease, water-free, is tested in this machine, torques in the grease torque testing machine must not exceed the values shown in table 8-8.

General Purpose Aircraft Lubricating Grease

This grease is intended for use in antifriction bearings, gear boxes, and plain bearings where reasonably low temperature operation and high temperature stability may be required. This grease must be a smooth homogeneous mixture consisting essentially of mineral oil and a gelling agent. The grease must be free from abrasive or otherwise undesirable fillers or impurities.

Gasoline and Oil Resistant Lubricating Grease

This grease is intended for use on gaskets and for the lubrication of the taper plug valves and other places in fuel and oil systems of aircraft. It is required to be a smooth, homogeneous compound of vegetable oils, glycerols, and soaps. The grease is not permitted to contain any solid fillers such as graphite, mica, sulfur, clay, asbestos, or chalk.

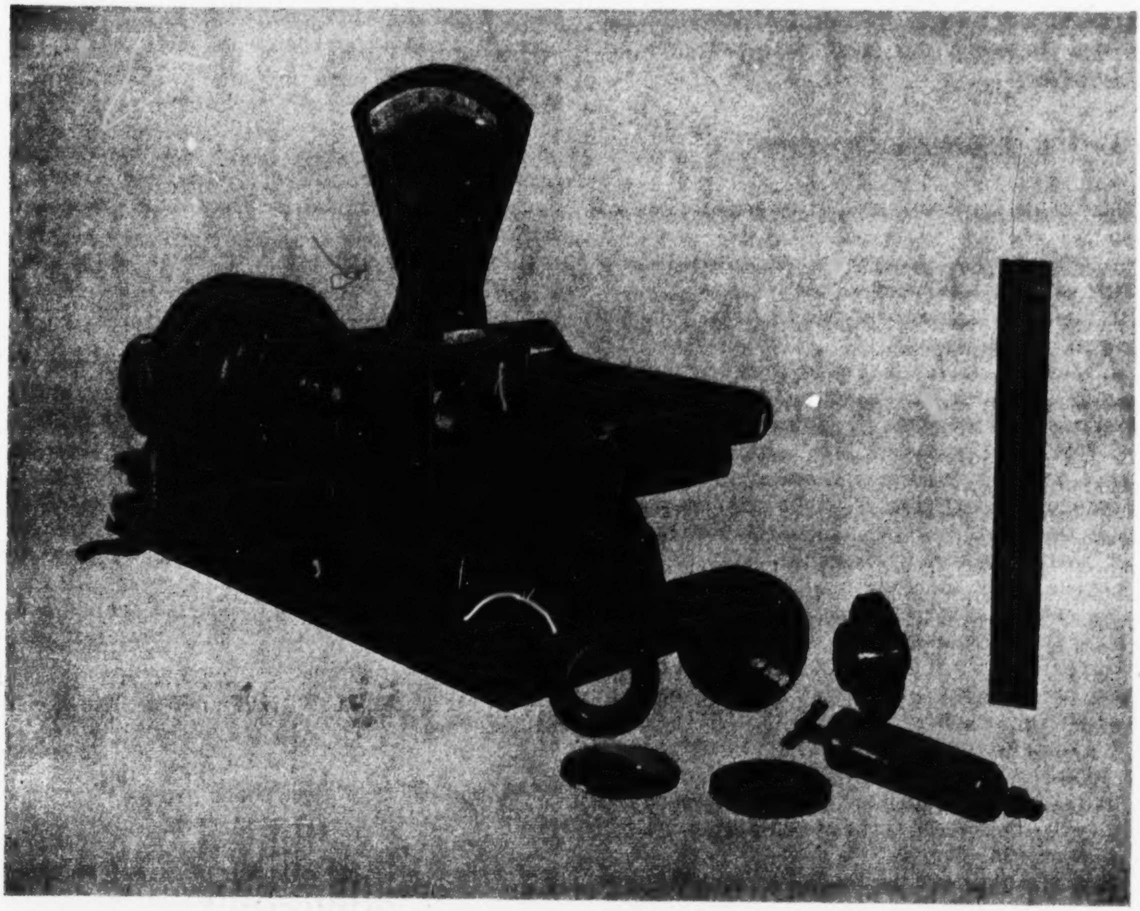

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Figure 8-5.—Grease Test Machine.

Table 8-8.—Torque Values, Water-Free

Ambient Temperature	Starting	After 5 minutes
Degrees F	Pound-inches	Pound-inches
70	30	7.5
0	65	15.0

Grease for Aircraft Gear and Actuator Screw for Low and High Temperatures

One military specification covers a grade of grease intended for general use on aircraft gears, actuator screws, and other equipment requiring a lubricant with a high load carrying capacity. It is not intended as an antifriction bearing lubricant but may be used on such bearings where equipment design requires the use of a single lubricant for both bearings and gears or power screws. The grease furnished under this specification must be a smooth, homogeneous mixture consisting essentially of a low temperature liquid lubricant, a gelling agent, and an extreme-pressure additive. The grease must be free from abrasive or otherwise undesirable fillers or impurities and must not be dyed an unusual color. The composition of the lubricant is not otherwise limited but substantial proportions of nonpetroleum materials are required to meet the volatility and low temperature requirements of this grease.

In addition to the usual chemical and physical tests, a performance test of gear wear is required. The apparatus for this test consists essentially of a brass and steel helical gear combination mounted as shown in figure 8-6. Wear is indicated by the loss of weight of the brass gear after being run on the driven shaft under various load conditions.

Automotive and Artillery Grease

One grade of grease is furnished for use in the lubrication of automotive and artillery material under all conditions of service where ambient temperatures range from minus 65° F to plus 125° F. This grease may be made of mineral or synthetic oil.

Extreme Pressure Grease

An extreme pressure grease is furnished in one grade. The grease, which has good anti-rust properties, is suitable for the lubrication of open or semi-enclosed gears (spur or worm) or any sliding or rolling metal surfaces where loads may be high and where the equipment may be exposed to salt spray or moisture. It is intended for use throughout the entire range of expected operating temperatures (approximately 0° F to 140° F).

A performance test of this grease is run on the Extreme Pressure Tester, shown in figure 8-7. This tester consists of a rotating structure mounted on ball bearings and driven through a cone-type worm and worm-wheel. The grease under test is painted on the worm and worm-wheel, all surfaces being completely covered. The worm is held in snug engagement with the wheel by means of a spring with an effective pressure of 100 pounds between the worm and wheel. The worm is driven by a motor belted to the worm shaft so as to rotate the structure in a reversing cycle approximately 1 1/2 times in each direction before reversing. The speed of mount rotation is approximately 4 rpm. The tester is operated for specific periods of time at stated temperatures, and the power utilized must not exceed maximum readings stipulated in the performance requirements.

Aircraft and Instrument Grease for Low and High Temperatures

One grade of grease is supplied for general use on aircraft and for instruments. This grease

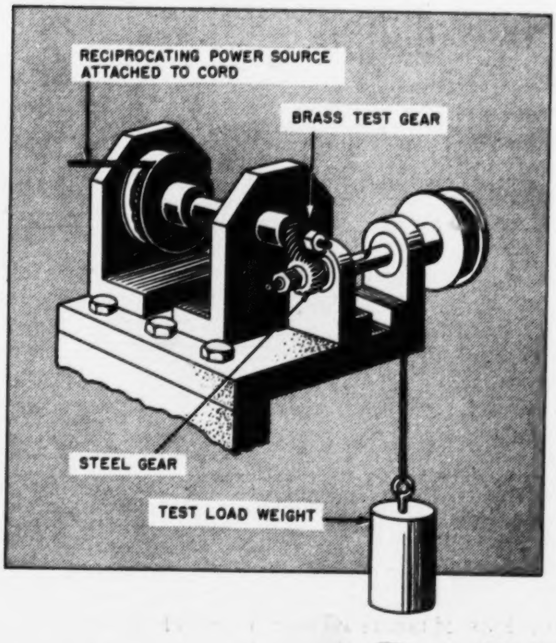

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Figure 8-6.—Assembly of gear wear tester.

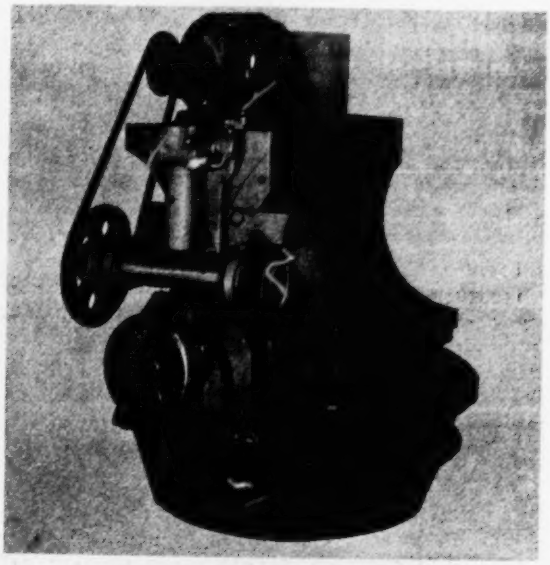

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Figure 8-7.—Extreme Pressure Grease Tester.

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is intended for use in ball, roller, and needle bearings, gears, and on sliding and rolling surfaces of such equipment as instruments, cameras, electronic gear, and aircraft control systems. It is particularly suitable for equipment which must operate at both very low and high temperatures. Its extremely low volatility is of advantage in preventing oil fogging in optical instruments. This lubricant does not contain extreme pressure or special antiwear additives and, therefore, only after performance evaluation is this lubricant considered suitable for such applications as aircraft actuators and similar equipment utilizing mechanisms having high unit bearing loads.

CHAPTER 9

QUALITY SURVEILLANCE

Quality surveillance consists of all measures necessary to determine and maintain the quality of fuels and lubricants in order that these products may be in a condition suitable for immediate use. Quality control, as applied in the refining and production segment of the petroleum industry, is generally understood to mean ensuring that the end product meets prescribed specifications. Quality control begins with production, when Quality Assurance Representatives ensure that contractors use the proper procedures to produce a product that meets specifications. Once the product becomes the property of the military services, quality surveillance begins. Products delivered to military activities have been completely tested at the point of origin, normally under the supervision of a military petroleum inspector. However, the surveillance of products after receipt by the Government is necessary in order to detect contamination or deterioration during handling and storage.

RESPONSIBILITY FOR QUALITY SURVEILLANCE

In the continental limits of the United States, each military department conducts its own quality surveillance program in accordance with its own needs. Duplication of laboratory facilities is avoided through close coordination among the departments when considering the establishment of any new laboratory.

Quality surveillance responsibility overseas is assigned on an area basis by joint departmental instruction. It is the responsibility of the department assigned a specific area to maintain laboratory facilities for testing samples of petroleum products in its assigned area. The department having physical possession of the product is responsible for quality surveillance including sampling for necessary laboratory tests. General instructions and minimum procedures to be utilized are contained in the Quality Surveillance Handbook for Fuels and Lubricants (Overseas Areas), MIL-HDBK-200.

Petroleum procurement inspection personnel are assigned to all important refining centers world-wide. These inspectors, known as Quality Assurance Representatives, assure that contractors comply with contractual requirements in the furnishing of petroleum products and services. Responsibility rests on the QAR for assuring the quality and quantity of petroleum products over which he has inspection cognizance. In addition, because of his technical skills and the specialized nature of the products, the QAR lends assistance in matters related to supply and transportation of petroleum products and may be called upon to investigate problems encountered at military installations.

IMPORTANCE OF QUALITY SURVEILLANCE

As we have seen in the previous chapter, essential product characteristics are established and published as specifications. The characteristics so listed consist chiefly in quantitative measures of the physical and chemical properties of the product which, taken together, are essential to make it the especially appropriate agent for its intended use. However, these properties, in turn, are dependent upon the composition of the product. Hence, any change in the composition of the product may result in such marked changes in its properties that it becomes unsuitable for its intended use.

The loss of essential characteristics in a product, unavoidably or otherwise, is always a serious matter. Even if it is known to have occurred, the appropriate disposition of the product can be determined only by a technically qualified person and offers only undersirable alternatives which normally involve loss of time, money, material, and the overall efficiency of supply operations. For example, the deteriorated product may be blended with larger quantities of the same product of high quality (this involves equipment and storage facilities not always readily available and thus may cause a decrease in the operable storage capacity of a depot and hence the efficiency of supply), or it may be downgraded (assigned for use where a lower grade of product would normally be employed provided it meets the requirements for the lower grade). Downgrading, however, can result in a serious shortage of a product at a time of great need. Downgrading necessitates segregation, careful planning, and supervision of issue, and may create an increased maintenance problem in an area.

When the loss of essential characteristics remains unrecognized, the issue of an off-specification product—such as an off-specification fuel to combat units—can produce critically damaging results, quite aside from problems of maintenance. Such products could cause the loss or serious damage of a submarine; failure of aircraft to get into the air, forced landings, or lack of power at a critical moment in combat; and the complete breakdown or sluggish operation of tanks and other ground combat vehicles. Any of these eventualities could result in loss of personnel and equipment, and might be the deciding factor in the success or failure of a tactical operation.

DETERIORATION OF PRODUCTS

Changes occurring while a product lies in storage become more marked as the product ages. The changes may be initiated or hastened by the conditions of storage, and are not normally observable by personnel handling the product. Therefore their discovery, before issue, is dependent upon adequate laboratory control programs. The most common forms of deterioration are: weathering, gum formation, and loss of additives, of tetraethyl lead, and of color.

Weathering

Weathering refers to the loss of the more volatile components of some products. Its effects are most noticeable in motor and aviation gasolines. As we have seen, these products are mixtures of liquid ingredients, some of which evaporate more readily than others. The rate of evaporation increases markedly with rises in temperature and produces sufficiently high gas pressures to rupture a container. For this reason, all tanks are vented to the air. The excess vapors escape through the vent and thus, during weeks or months of storage, a considerable proportion of the more volatile ingredients may be lost. Since the more volatile components of the fuel are required to provide easy starting in engines, and a plentiful supply of fuel during warm-up periods, the less volatile weathered fuel may give considerable trouble if issued for use in cold weather.

Gum Formation

Gum formation is the most common and troublesome form of deterioration suffered by internal combustion engine fuels. Gum formation is caused by the presence of the unsaturated hydrocarbons in the fuel which, in the presence of oxygen, tend to undergo chemical changes producing first gummy, and eventually resinous materials. The latter are insoluble and slowly settle out on the walls and bottoms of containers from which they are difficult to remove. The gummy substances remain dissolved but are difficult to vaporize. They are sometimes found as deposits in fuel lines; during vaporization of the fuel they may clog carburetor jets. In either case they have adverse effect upon the fuel supply. Carried mechanically by the rush of vapors to the combustion chamber, they may form sticky deposits on rings and valves thus decreasing efficiency of operation; in the chamber itself, their combustion is incomplete and results in excessive carbon deposits. The existence of gum in fuels, in greater that the allowable amounts, is certain to necessitate increased engine maintenance. Although gum or oxidation inhibitors are added to internal combustion engine fuels, these additives are effective for a limited time only and do not offer permanent protection.

Loss of Additives, of Tetraethyl Lead, and of Color

These forms of deterioration are considered together because their causes are not established with certainty, although all have been known to occur during storage. Each may be the postponed result of manufacturers' mistakes, of improper handling, or of contamination. Each deserves thorough technical investigation. Loss of oxidation inhibitors decreases the safe storage

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time of the fuel due to the possible early formation and rapid development of gum. The loss of tetraethyl lead decreases the power-producing characteristic of the fuel and is indicative of very serious deterioration, particularly in aviation fuels. Loss of color, itself, has no importance other than its psychological effect upon the consumer who invariably distrusts such a product.

CONTAMINATION OF PRODUCTS

A contaminated product is one to which has been added some material not normally present such as dirt, rust, water, or another petroleum product. Such admixture may modify the usual qualities of the product permanently or add new and undesirable characteristics. In either case, the contaminated product may be unsuitable for its intended use. Contamination may result from accident, inability or neglect to follow prescribed procedures, gross carelessness, or sabotage. In most instances contamination of a product can be detected by its unusual appearance, color, gravity, or odor. However, all products suspected of being contaminated should be reported to the laboratory as contamination can sometimes be determined only by laboratory tests.

Dirt

The causes for the presence of sand, clay, or loam in appreciable quantity in petroleum products should be investigated at once and remedial action taken. It may be the result of carelessness or of sabotage. Most commonly it is the result of inadequate cleaning and inspection of tanks or containers, or the use of muddy water to flush pipelines.

In light fuels such as gasoline, in cans or drums, dirt settles in a few hours. The clear fuel may then be drawn off and the bottom (4 to 10 inches) recovered by filtration through a dry chamois. An alternative is to decant the fuel into larger containers for further settling. In bulk tanks the settling may require 12 to 24 hours. The clear fuel may then be run off to clean storage and the bottom layer passed through gasoline filters, if available, or downgraded. Tanks and other containers should be thoroughly cleaned before reusing. In heavier fuels such as diesel oils or JP-5 jet fuel, settling is much less satisfactory. Filtration is recommended if practical. Otherwise it is usually necessary to downgrade the product. In the case of lube oils and greases, no remedial action can be taken. The product must be downgraded.

Rust

Rust is the common name for the product of corrosion which is formed when unprotected iron or some steel surfaces are subjected to prolonged contact with water or moist air. It is brittle and powders readily. It is insoluble in water and in petroleum products but may form troublesome suspensions because of turbulent flow in pipelines, the churning action produced while pumping into storage tanks, or the rough handling of small containers. Rust is a commonly occurring source of contamination when disused pipelines or containers are employed without proper cleaning. Its prevention in small containers—where it is most likely to occur—is best accomplished by thorough cleaning and subsequent rinsing of the container with a prescribed rust-preventive type oil or solution which will cling to the metal surface in a thin layer and provide temporary protection until the container can be filled with the product to be stored. While empty, the containers should be stored upside down. Active pipelines and large storage facilities do not normally permit the accumulation of rust in appreciable quantity. Rust may be removed from gasoline and heavier fuels by the same methods employed in removing dirt from these products.

Mill-Scale

Mill-scale is a magnetic product formed on iron and some steel surfaces during the manufacturing process. It is largely responsible for the blue-black appearance of such surfaces. It has been observed as a very serious contaminant in bulk products pumped through new pipes during the first few days or weeks of use. The scale is brittle and cracks readily. Corrosion begins at these cracks and proceeds to spread under the scale causing it to flake off. The scale is then carried along by the oil flow and is broken up still further before it reaches terminal storage. Here it may remain suspended for days. Settling is not, therefore, a satisfactory method of elimination. The scale is not removed completely by segregators and consequently, screens are quickly choked. Filtering of such stocks is recommended.

Water

Bulk Storage.—In bulk storage, water can very often be a reason for fuel contamination. Water is sometimes employed as a bottom, to a depth of a few inches, to underlie light products such as gasolines and jet fuels. However, the use of water bottoms should be avoided if at all possible, and only employed when authorized by proper technical authority. It is sometimes used to separate and prevent mixing of products when two products, such as motor gasoline and aviation gasoline, are to be pumped through a pipeline, one after the other. Again, this should be avoided if possible as there are better means for segregation of products. The legitimate and necessary uses of water provide ample opportunities for the contamination of light products unless they are controlled by strict adherence to standard operating procedures. Fortunately, water suspended in light products such as gasoline separates rapidly on standing; less rapidly in diesel oil and JP-5 jet fuel. In cold weather this settling may be delayed by the formation of ice crystals, which are lighter than water droplets. In suspension, these crystals may clog filters, fuel lines, or jets in equipment.

Water cannot be used in black-oil lines or tankage because, with this product, it can form more or less permanent emulsions. In transferring black oils from tank farms to smaller containers, segregators are helpful. The most effective precaution against water contamination is to ensure delivery of a well-settled product through a dry line into a dry container. In cold weather, even a small amount of water can cause the freezing of bottom outlet valves in rail tank cars and tank trucks.

Packaged Products.—In the case of packaged products, water may become a contaminant through the use of open or damaged containers, through improper storage and handling methods, and by the breathing which normally occurs in drums and cans. (Breathing is the reverse of vaporization and is caused by a drop in temperature. In breathing, cooled vapors condense to liquids, the interior pressure of the storage tank or container decreases, and air is sucked into the tank or container.)

Water contamination of fuels supplied to consumers in drums or cans can be avoided, when the turnover is rapid, by the application of prescribed methods of inspection, storage, and handling. However, long-term storage in drums, (strategic reserve stocks) cannot fail to result in some contamination. The condensation of some water from the moist air sucked in during the night is inevitable since this water settles and, therefore, is not expelled with product vapors during the heat of the day. During several weeks of storage, this water accumulates in surprisingly large amounts. Not only does it constitute direct contamination, which may have very undesirable consequences if transferred to equipment, but it is the cause of serious additional contamination by rust, and increases container maintenance. For this reason, periodic technical inspection is required and provision must be made for the regular replacement of such stocks at relatively frequent intervals. The length of intervals is determined by climatic and other conditions. Accumulated water can best be removed by decantation, settling, and refilling. Lacking time or facilities for this, a small pump may be employed to remove the lower layers from individual containers.

The most effective and proper protection for lubricants is to keep them well covered, preferably in inside storage. Should damaged containers permit water to contaminate engine or gear oils, the water may remove some of the essential additives. Even more undesirable is the fact that water tends to emulsify in the oil and does not settle out, thus decreasing effective lubricating action. Water can be poured off from greases. When this is done, about an inch of surface grease should also be removed. After removal, the surface grease should be burned or buried.

Microbiological Growth

Microbiological growth consists of living organisms that grow at the fuel-water interface. These organisms include protozoa, fungus, and bacteria, but fungus is the major constituent and the cause of most problems associated with microbiological contamination of jet fuels. Fungus is a form of plant life; it holds rust and water in suspension and is an effective stabilizing agent for fuel-water-sediment emulsion. It clings to glass and metal surfaces and can cause erroneous readings in fuel quantity systems, sluggish fuel control operations, and sticking of flow dividers. Microbiological growth is generally found wherever pockets of water exist in fuel tanks. It has a brown, black or gray color and a stringy, fibrous-like appearance. The presence of microbiological growth in fuel being delivered to aircraft is a reliable indication of failure of fuel filtration equipment. The most effective means for controlling problems of microbiological growth is through enforcement of good housekeeping practices regarding removal of water bottoms in storage tanks and general cleanliness of handling equipment.

Commingling of Products

Commingling of products may result from inadequate cleansing of lines or containers; from the use of unmarked or improperly marked containers; and from the mishandling of manifolds. In such cases it can be minimized by supervision sufficient to ensure strict application of the prescribed petroleum handling procedures. Commingling may also result from leaks in tanks or valves aboard tankers, and from leaky valves or insufficient protective facilities in shore installations. These sources can be minimized by proper inspection and maintenance procedures. Nevertheless, serious contamination of one product by another can and does occur occasionally in field operations. This is one of the most compelling reasons for the continuous inspection procedures and the routine testing programs prescribed by the military departments.

Commingling can be negligible or serious depending upon the product contaminated, the contaminating agent, and the amount of contamination. Some of the more important serious effects are:

1. Loss of power in fuels.
2. Increase in volatility (producing a fire or explosion hazard in kerosine or diesel fuels).
3. Increase in gum content.
4. Formation of heavy sludge.

RECLAMATION

Generally, suspected deterioration or contamination must be confirmed by laboratory tests. Reclamation refers to the procedure required to restore or change the quality of a petroleum product to meet the desired specifications. Before definite action is taken to reclaim a product, the following factors must be fully considered:

1. Contaminating agent or agents and source;
2. Degrees of contamination or variation in specifications of contaminated product from required specifications;
3. Probable end use of product in present condition—due regard being given to recent laboratory analysis, purchase specifications, established use limits (if any), and safety factors involved;
4. Probability or removing or nullifying undesirable effect of contaminating agent, or agents, so the product can be used for the purpose originally intended, or for some other end use;
5. Actual location and quantity of questionable product, probable need for unreclaimed or reclaimed product at its present or other location, and the estimated rate of consumption;
6. Availability of time, materials, equipment, and labor necessary to reclaim the contaminated product.

The procedures for reclamation include: (1) identification; (2) downgrading; (3) blending; (4) filtering; (5) dehydrating; and (6) inhibiting.

Identification

Packaged products to be reclaimed should be segregated by products. When container markings are obliterated or missing, examination of the product will generally facilitate segregation. For example, gasolines are generally identifiable by color; grades of lubricating oil by viscosity. Fuels of the same grade may be decanted into clean bulk storage, tested, and immediate disposition made according to the analysis. Further storage, packaging, and blending should be avoided. Appropriate laboratory tests are then run on representative samples. Each activity stipulates the manner in which containers are to be marked, but products packaged in the field and not intended for immediate consumption should also include one or more of the following: lot number, batch number, tank number, and date filled.

Downgrading

Aviation gasolines that cannot be reclaimed for use in aircraft engines by prescribed procedures may be downgraded, blended with low TEL content motor fuel, and used as motor fuel provided the final blend meets specified test limits. Contaminated high grade motor fuel originally designed for use in combat vehicles may be downgraded, or blended, if preferred, and used in transport or administrative vehicles and stationary engines in accordance with prescribed limiting factors. Slightly contaminated kerosine may be used for purposes other than lighting, and contaminated diesel fuels may be used in stationary engines or as fuel oil in accordance with limits specified. Contaminated jet fuels may sometimes be downgraded, or blended, if appropriate. However, due to the wide range of variables encountered when jet fuels are contaminated, no general statement regarding downgrading can be made.

Blending

All blending must be rigidly controlled and the correct percentages to be blended determined by the laboratory. The actual field blending must be closely supervised and when the resulting blend is of sufficient volume to warrant additional inspection, the laboratory should run sufficient tests on the field blend to determine whether this product meets the required purchase or use specifications.

Within prescribed limits, condemned aviation gasoline which cannot be reclaimed may be blended with low grade motor fuel to produce a higher grade motor fuel. Lubricating oils (except aircraft engine lubricating oils) of different viscosities that meet required purchase specifications may be blended to produce intermediate viscosity oils. However, the two products should be of the same type and intended for the same original purpose, and should differ only in viscosity or SAE number. The blending of oils to obtain intermediate viscosities should be done only in cases of emergency or when authorized by a cognizant activity, and then only in minimum quantities required.

Filtering

As previously mentioned, dirt and rust can be removed from gasoline by filtering through a chamois. A special type of filter is required for removing haze from aviation fuel that has deteriorated on long standing. This haze is due to the formation of insoluble lead compounds and, unlike dirt and rust, will not settle out.

Dehydrating

Moisture or water generally will settle out of the lighter petroleum products if they are allowed to stand undisturbed. In the case of flat bottom steel gasoline storage tanks, it is sometimes desirable to keep a few inches of water on the bottom, but excessive water noted while gaging should be bled off through the water draw-off. Removal of suspended moisture or finely divided water particles from the heavier petroleum products may be a most difficult operation. In some cases, the moisture will drop out on long standing. In others, it is necessary to raise the temperature of the product. (This procedure does not apply to aircraft engine lubricating oil.)

Inhibiting

As we have seen, aviation fuel generally contains an active added inhibitor. The applicable specification provides that a maximum content of approved inhibitors may be added to prevent the formation of gum and the precipitation of lead compounds. Specifications for motor fuel include a minimum oxidation stability. To meet this requirement, it is generally necessary to add an inhibitor which functions for all practical purposes, the same as that in aviation fuel. Any program for reclaiming aviation or motor fuel by inhibiting, or by filtering and inhibiting, must be carried out under the direct and constant supervision of qualified personnel, assisted by adequate laboratory facilties.

CHAPTER 10

SAFETY IN HANDLING PETROLEUM PRODUCTS

Although the handling of petroleum products presents many hazards, both bulk and packaged products can be handled safely and with remarkable freedom from accident if product characteristics are understood and proper precautionary measures taken. This chapter is concerned with those properties of petroleum products which relate to safety and with general safety precautions in handling these products. Special precautions to be observed in certain phases of petroleum handling—such as tanker operations—are discussed in appropriate chapters. Safety precautions for handling petroleum products afloat are published in BuShips Technical Manual (NavShips 250-000), chapter 9930; for 93; for shore activities they are published in NavDocks DM-8 "Fire Protection Engineering."

HAZARDS IN HANDLING PETROLEUM PRODUCTS

It has been said that 80,000 barrels of gasoline in a properly constructed storage tank is comparatively safe, while one pint of gasoline, spilled, is very dangerous. Although it is not recommended that gasoline be kept in the home, it has been stated—to emphasize a point—that a gallon safety can filled with gasoline and placed on a closet shelf would not be dangerous as long as the gasoline stayed in the can. However, to utilize the gasoline, the can must be opened and the gasoline poured out. When this is done, a hazard is created. In short, the hazard is not in the storing but in the handling. Moreover, the hazard is not in the gasoline itself, but in its vapors.

Vapors from all petroleum products are hazardous because:

1. They constitute fire and explosion hazards.
2. They are toxic to the human body.

Since it is the vapors from petroleum products which create the greatest hazard, the vapor characteristics should be understood. Vapors from petroleum products have been known to travel some distance and, upon reaching a source of ignition, to flash back to the point of origin, causing a fire. Flash-backs are extremely dangerous and are usually fatal to anyone caught in them. Moreover, vapors from petroleum products are heavier than air and will settle in low places. They will remain in tanks indefinitely unless removed by steaming or ventilating.

Although vapors constitute the greatest hazard in handling petroleum products, liquid products are also dangerous in that skin contact of certain petroleum products can cause skin irritations.

The two major types of hazards in handling petroleum products are: (1) fire and explosion, and (2) hazards to personnel. Both types are created primarily by the vapors from these products.

FIRE AND EXPLOSION

Classification of Products

Precautionary measures must be taken to prevent fire and explosion when handling any petroleum product. The degree of hazard involved depends on the properties of a given product. Therefore, for safe handling purposes, petroleum products are divided into groups or classes according to the temperature at which the product will give off flammable vapors.

Any material which can be ignited easily and which will burn with unusual rapidity is said to be flammable. (The terms flammable and inflammable are identical in meaning, but the former is preferred since the prefix in suggests non flammable.)

All petroleum products, being composed of carbon and hydrogen, will burn and are therefore combustible materials. However, classification

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for safe handling purposes distinguishes products according to their tendency to burn.

Combustible Liquids.—According to the National Fire Protection Association (NFPA) Standards, combustible liquids are those liquids having flash points at or above 140° F and below 200° F.

Flammable Liquids.—According to the NFPA Standards, all liquid petroleum fuels which give off flammable vapors below 140° F are considered flammable liquids.

Volatile Products.—Products which tend to vaporize; that is, give off flammable vapors at comparatively low temperatures are said to be volatile. Because volatile products such as gasoline and JP-4 jet fuels will give off sufficient vapors to be flammable at relatively low temperatures, they are the most hazardous of all petroleum products to handle. For example, gasoline has a flash point of about -45° F and JP-4 jet fuel has a flash point slightly higher, while crude oil has a flash point of about 60° F. This varies, however, according to the source of the crude oil. Volatile products such as gasoline and JP-4 jet fuel are normally handled at atmospheric temperatures above -45° F and, therefore, give off sufficient vapors to flash or burn at all times. Products which give off flammable vapors only above 100° F and are relatively nonvolatile are relatively safe to handle at ordinary temperatures and pressures. Such petroleum products as kerosine, JP-5 jet fuel, diesel and light and heavy fuel oils are included in this category.

It is noted, however, that if products such as kerosine, JP-5 jet fuel, diesels and fuel oils are handled at elevated temperatures they are just as hazardous as the volatile products. For example, kerosine, which has a flash point of about 110° F will not ignite at ordinary atmospheric temperatures, but if it is heated above 110° F will give off sufficient flammable vapors to burn or explode. All products which have a flash point above 100° F when heated to temperatures equal to or higher than their flash point, should be treated as volatile products with respect to fire and explosion hazards.

Vapor Explosive Range

When vapors from petroleum products are mixed with the proper amount of air, they form explosive mixtures within a limited range, usually called the explosive range or explosive limits. (Although the term explosion has several different meanings, it refers here to the instantaneous burning of a mixture of flammable material in air.) While the terms flammable limits or combustible limits are sometimes used synonymously with explosive range, the latter is more commonly employed in order to distinguish rapid combustion from slower oxidation reactions.

The explosive range for different petroleum products varies considerably, but the explosive range shown in figure 10-1 is useful for general purposes. As illustrated, the hydrocarbons in gasoline vapors form explosive mixtures when mixed with air in a range stated to be from 1 percent to 6 percent by volume (although this varies with atmospheric temperature and pressure). The upper explosive limit is that point above which the mixture does not ignite because it is too rich. For example, when the gasoline-air mixture contains 7 percent gasoline vapors, the mixture is beyond the upper limit and does not ignite. The lower limit is that point below which the mixture does not ignite because it is too lean. For example, a mixture containing less than 1 percent gasoline vapor does not ignite. If, however, the mixture is within the explosive range, it will ignite instantaneously when a spark or flame is introduced. If the mixture burns in an open space, where the hot gases resulting from the combustion have plenty of room for expansion, there is no explosion; if the mixture ignites in a confined space, an explosion takes place, as a result of the rapid expansion of volume or increase in pressure.

Factors Necessary for Combustion

Three factors are necessary for combustion: (1) fuel in the form of vapor; (2) oxygen from the

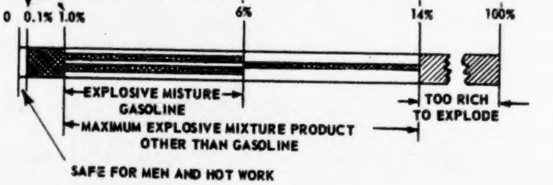
0.1% LOWER TOXIC LIMIT
1% LOWER EXPLOSIVE LIMIT
UPPER EXPLOSIVE LIMIT FOR GASOLINE
UPPER EXPLOSIVE LIMIT FOR METHANE
0
0.1%
1.0%
6%
14%
100%
EXPLOSIVE MISTURE GASOLINE
TOO RICH TO EXPLODE
MAXIMUM EXPLOSIVE MIXTURE PRODUCT OTHER THAN GASOLINE
SAFE FOR MEN AND HOT WORK

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Figure 10-1.—Vapor explosive range (percent by volume).

air; and (3) sufficient heat to raise a combustible material to its ignition temperature. All three of these factors, illustrated in figure 10-2, must be present in the same place, at the same time, in order to have fire.

Fuel.—When anything burns, it is not the actual substance which is consumed by the flame, but the vapor of the substance in combination with the oxygen of the air. A piece of wood held in a flame will not catch fire until it has been heated to a point where vapor is given off.

As previously stated, volatile petroleum products which give off flammable vapors at or below 100° F, constitute greater fire hazards than those products classified as nonvolatile. Gasoline, a highly volatile, flammable product, will vaporize at ordinary temperatures and pressures. Therefore, at ordinary temperatures and pressures, gasoline furnishes the first factor necessary for combustion.

Oxygen From The Air.—It has been previously stated that a gasoline vapor-air mixture containing from about 1 percent to 6 percent gasoline vapor would have sufficient fuel (vapor) and sufficient air (oxygen) to burn or explode. Thus, if anywhere from 1 to 6 cubic feet of gasoline vapor were introduced into a box containing 100 cubic feet of air, a mixture would exist which would readily ignite or explode upon the introduction of a spark or flame.

It has also been stated that combustion will not take place if the mixture is either too rich or too lean. For example, if a beaker is filled with gasoline and a sparking device placed at the surface of the liquid, the gasoline will not ignite because there is insufficient air. If however, the flame is held just above the beaker, combustion will take place. The same principle applies to full and empty containers. Under normal conditions, the vapor space in a full gasoline tank is too rich to ignite. It is the empty tank, or one containing just a small amount of gasoline, which has sufficient air, mixed with the gasoline vapor, to cause a fire or explosion if a spark or flame is introduced. For example, 1 gallon of liquid gasoline will give off about 38 cubic feet of vapor. This vapor, when mixed with air (lower explosive limit), is sufficient to form 3800 cubic feet of vapor-air mixture in the explosive range.

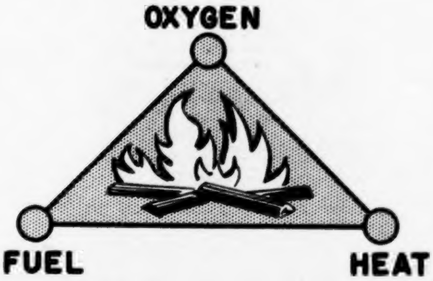

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Figure 10-2.—Factors necessary for combustion.

Heat.—Sufficient heat to raise the fuel to its ignition temperature is sometimes supplied intentionally. For example, open flames and sparks are intentionally employed in fired heaters and motor vehicles. However, the spark or flame may be unintentionally supplied by a number of sources if necessary precautions are not taken. Accidental ignition can result from a variety of causes, including open flames and sparks from various sources. Spontaneous combustion is another source of heat, which will ignite flammable vapors, if present.

Since all petroleum products, at given temperatures and pressures, furnish the first factor necessary for fire—namely fuel in the form of vapor—all possible sources of ignition must be effectively controlled in the presence of these products. Because of the importance of these sources of ignition in fire precautions, they are discussed at some length.

Sources of Ignition

Open flames from mechanical work and repairs involving hot work such as burning, cutting, and welding are obvious sources of ignition. Similarly, smoking in the vicinity of petroleum products is an obvious fire hazard. Sparks from cigarettes, cigars, and pipes are known to have caused serious fires, as have flames from automatic lighters that open and light with a single motion. Matches are another source of ignition. Still other sources which are equally hazardous, although perhaps less obvious, include static electricity, stray electric currents, friction, sparks and shorts originating in electric circuits, and spontaneous combustion.

1. Static Electricity.—The dangerous feature of static electricity in the presence of petroleum products is the spark discharge resulting

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from the accumulation of static electric charges. In its more noticeable forms, static electricity can be observed as in lightning. In its milder forms, as a relatively minute discharge between two pieces of oppositely charged material, static electricity is not readily noticeable. However, sparks created by static electricity can ignite flammable vapors, if the spark is hotter than the ignition temperature of the vapor.

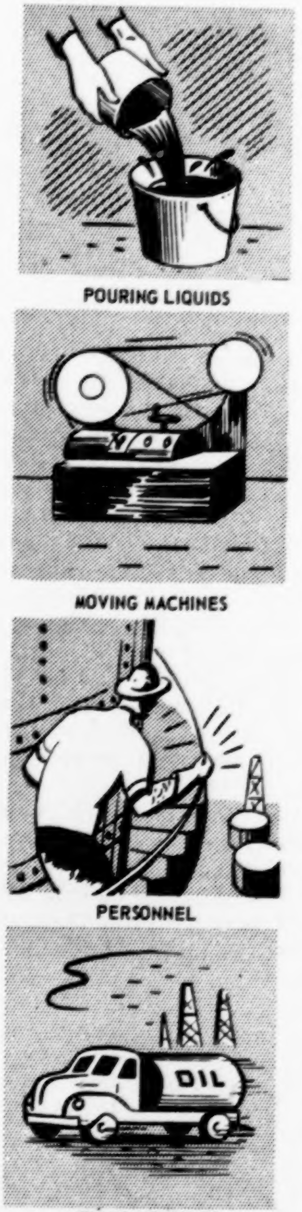
Static electricity can be generated in a number of ways, some of which are: (a) agitation of petroleum liquids; (b) moving machinery; (c) personnel; and (d) moving vehicles. (See fig. 10-3.)

(a) Agitation of Petroleum Liquids.—Petroleum liquids, being of high electrical resistivity, are capable of building up an electrical charge when subjected to agitation or friction. The flowing of these liquids through piping, agitation within a container, or movement such as pouring or spraying creates sufficient friction to generate electrical charges, resulting in a spark to a substance at a different potential.

For example, if a volatile product is pumped into a tank truck through a pipe line inserted into the dome but not electrically bonded to the truck, a high voltage static charge could be built up in the tank truck due to the flowing stream. This could result in a spark's jumping between the tank truck and the filling connection and igniting the flammable vapors. Another example is the pumping of petroleum products into a storage tank through an overhead or top connection. In this case, a high voltage static electricity charge is built up on the surface of the oil by the free fall of the product through the vapor space of the tank. Trouble from such cases is eliminated by pumping the product into the tank through a connection in the shell just above the bottom of the tank.

Numerous accidents have been traced to static electricity created by the agitation of petroleum liquids. One fire which consumed 120,000 barrels of crude oil in a storage tank was traced to the fact that a tin can, which had fallen into the top of the tank, became charged as a result of the accompanying agitation. When the can approached the metal shell or side of the tank, a spark resulted, and this ignited the vapors from the oil.

Protection against static electricity consists of dissipating static charges before they reach sufficient magnitude to be dangerous. This is accomplished in several ways, the most common method being grounding.


POURING LIQUIDS

MOVING MACHINES

PERSONNEL

MOVING VEHICLES

132.76

Figure 10-3.—Static electricity can be generated by (1) the pouring of petroleum liquids; (2) moving machinery; (3) personnel; and (4) moving vehicles.

(b) Moving Machinery.—Static electricity is generated in and around the moving parts of machines, particularly in dry atmospheres. Grounding of machines prevents the accumulation of dangerous static charges. Moving belts which are not electrically conductive, such as those employed for conveyors and power transmission, are also sources of static electricity. One method of combating this source is the use of rubber belting containing a conducting component.

(c) Personnel.—Vapors from certain flammable petroleum products can be ignited by the discharge of static electricity accumulated on ungrounded persons. In enclosed hazardous areas conductive flooring is installed and personnel should wear conductive shoes.

(d) Moving Vehicles.—Moving trucks and other moving vehicles are capable of generating static electricity. Whether or not this constitutes a serious hazard is a controversial issue. Although the National Fire Protection Association at one time required trucks to drag ground chains, the Association has now dropped this requirement.

2. Stray Electric Currents.—These currents usually originate in an electric generator or transmission system from which they flow into pipe lines and other metal parts paralleling railroad and streetcar tracks. Rail bands and heavy parallel conductors are a protection against these stray currents.

3. Sparks And Shorts Originating In Electric Circuits.—Sparks and shorts originating in electric circuits are hazardous. Common examples of sparks are those resulting from electric switches and from breaking electric bulbs. Because these are sources of danger, special lighting systems, special flashlights, and other special electric equipments are required for use in hazardous areas. Shorts can cause conductors to overheat sufficiently to ignite petroleum vapors. Electrical equipment used in hazardous areas should conform to the National Electrical Code requirements.

4. Spontaneous Combustion.—Certain materials such as vegetable oils and vegetable fibers soaked in oil are subject to slow oxidation when exposed to air at normal temperatures. If large masses of these materials are piled and allowed to stand, the heat liberated from the slow oxidation process is not allowed to escape and the temperature of the mass rises. If this heating is allowed to proceed, the material reaches its ignition temperature and starts to burn. This process is known as spontaneous combustion. Thus, accumulation of oily rags or paint-soaked rags in combustible buildings and containers is a cause of fires. When flammable petroleum products are in the vicinity, any such fire, though small in its beginning, can become the ignition source for a major fire. For this reason, materials subject to spontaneous combustion must be stored in a way least likely to accelerate oxidation and most likely to cause any heat of oxidation to be absorbed by the surroundings.

Precautions Against Fires and Explosions

The absence of any one of the three factors necessary for combustion prevents the occurrence of fires and explosions. However, in handling petroleum products, it is not practical to eliminate air. Prevention of fires and explosions can therefore be best accomplished by: (1) reducing or controlling the discharge of vapors which furnish the fuel necessary for combustion; and (2) eliminating sources of accidental ignition.

Some precautionary measures to be strictly observed when handling petroleum products are listed below. Most of these precautions apply to the handling of any flammable or volatile product at ordinary temperature, and higher flash or less volatile products at high temperature.

1. Reducing Or Controlling The Discharge Of Vapors

a. Take care that no spills occur.

b. Avoid spills from overflow when loading storage tanks by gaging tanks prior to loading.

c. Never neglect leaks. Make frequent inspections for leaks in tank seams, tank shells, and pipe joints.

d. If spills or leaks occur, clean them up immediately. Soaked ground should be washed with water or covered with sand or dry earth. The area should be policed until flammable vapor has been eliminated.

e. When temperatures are excessively high, cool storage tanks by sprinkling, or by playing water over them.

f. Keep containers for volatile products, whether empty or full, closed tightly.

g. Beware of empty fuel containers.

h. Insure proper ventilation of all enclosed spaces in which vapors may accumulate.

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2. Eliminating Sources Of Accidental Ignition

a. Do not smoke.

b. Do not carry "strike anywhere" matches or automatic lighters that open and light with a single motion.

c. Do not perform any mechanical work or repair involving hot work such as burning, cutting, or welding, unless a permit is issued by proper authority.

d. Inspect electrical apparatus frequently and correct any condition likely to cause sparking.

e. Open switches and pull fuses before work is done on electrical equipment.

f. Shut off gasoline tank truck engines during the entire period of filling or discharging unless the truck is designed for engine operation, to drive transfer pumps through a power take-off.

g. Ground flammable fuel hose nozzle to the tank before starting the flow of fuel. Maintain this bond throughout the filling operation.

h. Never load or unload volatile or flammable products during electrical storms.

i. Use only self-closing metal receptacles for discarding oily waste or rags and dispose of such collections daily.

j. Never use volatile petroleum products such as gasoline for any cleaning purpose.

k. Keep gage tape in contact with gage hatch during gaging operations.

l. Immediately remove any clothing which has become soaked with fuels.

3. Safety Precautions For Handling JP-4 Jet Fuel:

In addition to the safety precautions required for handling all volatile fuels, Grade JP-4 jet fuel, because of its tendency to accumulate and discharge static electricity and its low vapor pressure, requires additional handling precautions. Like other volatile fuels, JP-4 still requires a source of ignition. Unlike the other volatile fuels, the static electricity generated in pumping, transferring and loading JP-4 is an inherrent source of ignition which requires careful handling to control. JP-4 jet fuel is unique in that its rate of vaporization under most handling conditions will create an atmosphere (vapor/air) well within the explosive range, within the tank above the liquid surface. Where the atmosphere within a fixed roof tank storing gasoline will normally be too rich to be ignited or to burn within the tank, in the case of JP-4, any ignition at gaging hatches, vents (including filler necks on aircraft fuel tanks or cells) will travel into the tank and cause violent combustion (explosion). This hazard is not normally present in the case of Grade JP-5 jet fuel because of its relatively high flash point (140°F). To minimize the generation and accumulation of static electric charge in JP-4 jet fuel, the following procedures and/or precautions are recommended:

a. Do not use overhead fill lines which permit a free fall of product through the air.

b. The entrance of air into fill lines should be minimized or eliminated if practicable.

c. The pumping of mixtures of water and fuel and the maintenance of water bottoms should be kept at an absolute minimum or eliminated.

d. When loading vessels, do not exceed loading rates in excess of 3 feet per second (about 1000 barrels per hour through 12-inch line) through loading lines into tanks until discharge outlet has been covered by a minimum of 3 feet of product. Thereafter normal loading rate may be resumed. The loading rate applies to the flow into each tank. The total loading rate shall not exceed the sum of the allowable rates for the individual tanks filled. If there is evidence of turbulence or splashing of the product in a tank after the discharge outlet is covered by the specified 3 feet of product, the reduced loading rate shall be continued until turbulence ceases.

e. Ullages, water soundings, temperatures, and samples will not be taken on any tank until at least 20 minutes after the tank has been topped-off and flow into the tank has ceased.

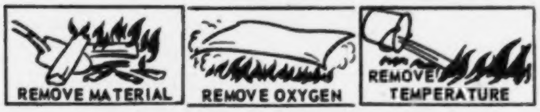
f. The rate of flow into a fixed roof shore tank when liquid levels are below 6 feet, should be reduced to below 3 feet per second.

g. Where available, floating roof tanks are preferred for JP-4 storage, since such tanks eliminate the vapor space and provide a ready path for dissipating a static charge. At low levels when the roof is resting on supports the same precautions as outlined in (f) above should be observed.

h. Where feasible the storage of JP-4 in concrete tanks or other poor electrical conducting materials should be avoided.

Principles of Extinguishing Fires

In order to extinguish a fire, one of the three factors necessary for combustion must be removed, as illustrated in figure 10-4.



132.77
Figure 10-4.—Principles of extinguishing fires.

This may be done by any one of the following principles:

Starving.—If the fuel is removed from a fire, it is extinguished by starving. This may sometimes be done in a petroleum fire by cutting off the flow of oil.

Smothering.—If combustion-supporting oxygen is removed, the fire is extinguished by smothering. The smothering principle is employed in most petroleum firefighting devices as it is the most effective means of fighting such fires. The use of foam, carbon dioxide, dry chemical, steam, and sometimes sand, is based on this principle.

Cooling.—If heat is removed from a fire, the fire is extinguished by cooling. In ordinary fires, this is ususlly done by the application of water. However, water alone is not used in fighting petroleum fires because a jet of water striking into the surface of burning petroleum will disperse the petroleum and thus spread the fire. Also, water, having a greater density than oil, is likely to sink through the oil without its normal cooling effect. However, the principle of cooling with water may be utilized in fighting petroleum fires by the use of water fog nozzles. Water fog will extinguish an oil fire by a combination of cooling and smothering. Water should not be used around electrical equipment, however, as it is a conductor of electricity.

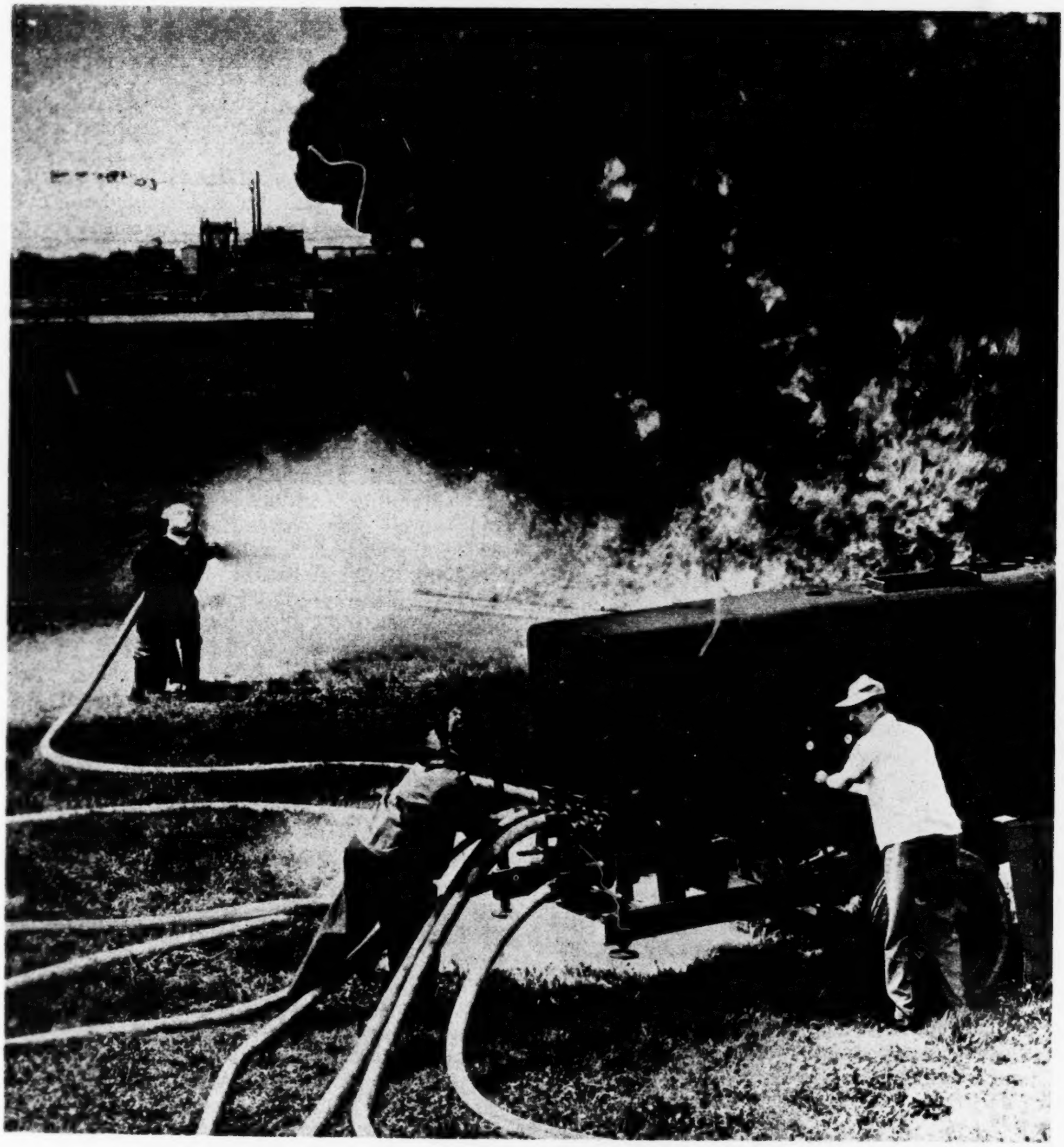
It should be remembered that water is very valuable for preventing the spread of petroleum fires. Water sprayed on tanks prevents the contents from reaching the point at which they will ignite from nearby flames. Water is also used to cool pipe lines, tanks, and other structures subjected to the heat from a fire in order to prevent them from failing and possibly adding more fuel to the fire.

Methods of Extinguishing Fires

New firefighting methods are being developed constantly. This chapter does not attempt to describe all types of extinguishers and systems, nor to serve as a manual on this highly specialized subject. Only general information on the types of fire extinguishers used in fighting petroleum fires is presented in the following paragrphs:

Foam Extinguishers.—Foam is an aggregate of tiny gas filled or air filled bubbles, lighter than the lightest oils, which is used to form a fluid blanket floating on the surface of flammable liquid to smother the fire by the exclusion of air. There are two types of foam; "Mechanical," which is produced by the addition of a liquid foaming agent to water and "Chemical" which is produced by combining an alkaline salt solution (usually bicarbonate of soda) and an acid salt solution (usually aluminum sulphate) to form a gas (carbon-dioxide) in the presence of a foaming agent which causes the gas to be trapped in bubbles to form a tough fire resistant foam. The two powders required to make chemical foam are commonly known as A and B, a single blend of all dry chemicals necessary and a special single blend of dry chemicals to produce "alcohol" type foam when mixed with water for use in single powder generators.

Production of Foam.—Foam may be produced in continuous foam generators, pressure type foam generators, foam hose streams and 2 1/2 gallon stored solution extinguishers. Liquid petroleum product storage tanks (except floating roof tanks) are usually protected by a fixed pipe distribution system pressurized by motor and pump. For small petroleum fires portable foam generators may be used. The mobility of mechanical foam producing systems make them highly desirable for extinguishing petroleum product fires. The foam generator shown in figure 10-5, ensures proper mixture of mechanical foam with water and air for attacking the fire. It is provided with portable hoseline foam outlets. Special nozzles provide for delivery of foam in a straight stream over long distances or in a protective cone-shaped curtain, depending on fire conditions.



132.78

Figure 10-5.—Triple-pump pressure-foam generator.

Carbon-Dioxide Fire Extinguishers.—This type of extinguisher holds liquid carbon dioxide under pressure. When the extinguisher valve is opened, the pressure is released. Extinguishers are made with both disk valves and seat valves. When the disk type valve is pierced, the entire contents of the cylinder are discharged, although a temporary shut-off is provided. The seat-type valve permits any desired amount of gas to be discharged. When the valve is closed, the remainder of the gas can be saved for future use. The liquid carbon dioxide, upon contact with air, turns into a gas which blankets the fire by shutting off the supply of oxygen. It also has a cooling effect.

The carbon-dioxide extinguisher can be used effectively to put out oil fires which burn both vertically and horizontally, such as a waterfall of flame from a broken pipe, or burning oil pouring from a broken container over a bench to the floor. The steps in using the carbon-dioxide extinguisher are shown in figure 10-6.

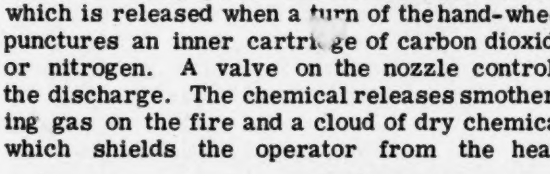
Dry Chemical Extinguishers.—These extinguishers, are excellent extinguishers for petroleum fires. Dry chemical extinguishers contain chemically processed bicarbonate of soda which is released when a turn of the hand-wheel punctures an inner cartridge of carbon dioxide or nitrogen. A valve on the nozzle controls the discharge. The chemical releases smothering gas on the fire and a cloud of dry chemical which shields the operator from the heat.

Carbon Tetrachloride (Vaporizing Liquid) Extinguishers.—The use of carbon tetrachloride extinguishers has been specifically prohibited for use by the Navy because of the extreme personnel hazard created by the extremely toxic decomposition products (primarily phosgene gas).

HAZARDS TO PERSONNEL

Vapor Toxic Effect

The principal hazard to persons handling petroleum products lies in the vapor toxic effects. Vapors given off by crude petroleum, gasoline, and other petroleum products cause anaesthetic effects when inhaled. Petroleum vapors in a concentration of 0.1 percent by volume may cause slight vertigo at the end of 6 minutes; 0.5 percent can cause vertigo, to the extent of inability to walk straight, in 4 minutes. Longer exposure or greater concentration may cause unconsciousness or death.



1
CARRY TO FIRE AND SET ON GROUND
2
UNHOOK HOSE
3
PULL PIN IN VALVE WHEEL
4
TURN VALVE... DIRECT GAS AT BASE OF FIRE

132.79

Figure 10-6.—Steps in using carbon dioxide extinguisher.

The maximum permissible content of petroleum vapors for any compartment or tank which is to be entered by persons has been fixed at 0.1 percent by volume. This limit is sometimes called the lower toxic limit. A comparison between the lower toxic limit (0.1 percent) and the lower explosive limit (1.0 percent) is shown in figure 10-1. It should be remembered that the concentration of vapors which can be tolerated by a man is far below that required to produce explosive mixtures with air.

First symptoms of exposure to toxic vapors are headaches, nausea, and dizziness. Recovery from these early symptoms is usually prompt after removal to fresh air. However, if men are overcome by vapors, they should receive immediate medical attention. First aid consists of the prevention of chilling and of artificial respiration if breathing has stopped.

Although jet fuels do not contain tetraethyl lead, they may contain more toxic aromatics than aviation gasolines. They should, therefore, be handled with the same health precautions as apply to leaded gasolines.

Lead Poisoning

The toxicity of heavy concentrations of vapors from gasoline is increased if the gasoline contains tetraethyl lead, added for antiknock purposes. This lead compound may be inhaled with the fumes or may enter the body through the mouth or by absorption through the skin. No matter how it enters the body, tetraethyl lead is poisonous.

Although the amount of tetraethyl lead blended with automotive gasoline is very small, the hazards of tetraethyl lead may arise when bulk gasoline facilities are involved. No one should enter a storage tank which has contained leaded gasoline unless special precautions are followed. Among other precautions, special protective clothing and a fresh air hose mask must be worn until such time as the tank is declared lead-free.

Lead poisoning may occur from repeated exposure to gasoline vapors in an enclosed or inadequately ventilated area where leaded gasoline has been spilled in considerable quantity. There is also danger of lead poisoning from fumes given off by stoves or other gasoline burning equipment in which leaded fuel is used. Adequate ventilation should be ensured. If operating personnel are exposed persistently to leaded gasoline, they should be rotated on the job in order to limit the period of individual exposure.

Injury to Skin and Eyes

Volatile products such as gasoline and JP-4 jet fuel may cause skin irritations if allowed to remain in contact with the skin, particularly under soaked clothing or gloves. Clothing or shoes through which any fuels have soaked should be removed at once. Fuel should be washed from the skin with soap and water. Repeated contact removes the protective oils from the skin and causes drying, roughening, chapping, and cracking and, in some cases, infections of the skin. Oil-resistant rubber gloves should be worn as protection by persons handling petroleum products.

If volatile fuels get into the eyes, first aid should be given immediately. After copious washing with water, sterile olive oil, castor oil, or mineral oil may be applied to the eye, and medical attention should be secured.

Swallowing Petroleum Products

If a person swallows a petroleum product, first aid should be given immediately. Giving the victim a large quantity of warm, salty water to drink in order to induce vomiting is an effective aid. Medical attention should be secured immediately.

Precautions Against Hazards to Personnel

1. No person should enter tanks or storage spaces which have housed petroleum products until such spaces have been tested by qualified personnel and declared safe for men.

2. If necessary to enter spaces which are not known to be safe, do not enter without special equipment and without having obtained instruction in use of this equipment. (Although this precaution seems obvious, many deaths have resulted from failure to observe it. A casualty aboard a tanker illustrates this point. Two men were working in the forward pump room and after some time failed to emerge. A third man, without stopping to don the required equipment, went down into the pump room to investigate. The third man did not return. All three died from the effects of toxic vapors.)

3. If symptoms such as headache, dizziness, or nausea are noted among persons handling petroleum products, such symptoms should be taken as a warning of the presence of dangerous amounts of petroleum vapors in the air. All exposed persons should be sent out of the area at once.

4. Care must be taken to avoid spilling petroleum products. As previously stated, clothing should be removed if volatile fuels have been spilled on it. This should be done in a well-ventilated space because of the danger of flammable vapors, and the resultant fire hazard. For example, a person having gasoline on his clothing entered a small locker room where another man was smoking. A spark from the cigarette ignited the vapors from the gasoline-soaked clothing. As a result, two lives were lost.

5. Volatile fuels should never be used for cleaning purposes.

SAFETY DEVICES AND EQUIPMENT

The U. S. Navy Manual of Safety Equipment (NavExos P-422), issued by the Safety Branch of the Office of Industrial Relations, Navy Department, provides data regarding the design, construction, operation, and limitations of articles of safety equipment most generally used by the Navy. Based largely on this manual, the remainder of this chapter discusses, in a general way, a few safety devices and articles of safety equipment commonly encountered in the handling of petroleum products.

Flame Arresters

A flame arrester is any device used for preventing the passage of flames from or into closed spaces. Flame screens which are one type of flame arrester, diffuse the heat and thereby lower the temperature. These screens, (usually 40-mesh) placed in the flow of flammable gases, will not permit any flame which occurs—whether accidentally or intentionally—on one side the screen to pass through its openings. Flame arresters may also consist of bundles of small tubes, each tube being sufficiently small in diameter to prevent the passage of flame.

Flame screens are used in gas furnaces to prevent the flame inside the furnace from igniting any gas which may escape to the outside. Flame screens are also used in some internal combustion engines between the carburetor and the fresh air intake. On tankers, flame screens are used at the mouth of the vent pipes which extend up the mast.

Portable Lighting

Portable electric lamps and flashlights are designed for use in atmospheres containing, or likely to contain, flammable gases and vapors. These portable hand lights obtain their power from self-contained dry-cell or storage batteries. The essential features of the lamps are that they are so designed that: (1) the accidental breaking of the lens and bulb in a flammable atmosphere while the lamp is in operation will not cause ignition of gas; and (2) there will be no difference in electric potential between any two points on the exterior of the lamp. The bulb is mounted in such a way that, should the lens and bulb be broken, the base of the bulb would be ejected from the socket so quickly that the heated filament would not have time to ignite the gas.

Safety Cans for Flammable Liquids

Safety cans are designed for the safe handling of gasoline, naphtha, and other highly volatile, flammable liquids in quantities up to 10 gallons. These cans are made for use inside buildings which are not provided with special storage rooms of proper construction. They are also used for transporting such liquids within local outside areas.

Each can is cylindrical in form and has a self-closing valve which is opened through a valve-actuating linkage by manual pressure applied to either the carrying handle or an independent control lever. Internal pressure in excess of 5 pounds per square inch is relieved either through an independent pressure-relief valve or by overcoming the spring pressure on the pouring closure or the filling closure.

Both the filling and pouring openings are provided with double screens of such design that they serve as flash-back arresters in the event the flammable vapor should be ignited outside the can. These screens can be readily removed and replaced without forcing, thus facilitating frequent inspection and cleaning. The valves are leakproof, so that the can, when filled with liquid, can be inverted without any danger of leakage.

The stability of the can is such that it will not tip over of its own accord when it contains liquid and is placed on an inclined surface which forms an angle of 30 degrees with the horizontal.

Combustible Gas Indicators

To detect the presence of flammable gases or vapors in the atmosphere, instruments known as combustible gas indicators are used. (Commercially, these are known by various trade names such as Explosimeters and Vapotesters, the trade name depending on the manufacturer.) In using a gas indicator, a sample of the combustible atmosphere is drawn through an analyzer unit where it comes in contact with the surface of a heated platinum filament. The filament over which the sample passes, known as the detector filament, has a surface catalytically activated to burn the vapors. When vapors are present, their burning on the filament will produce an increase in temperature and as a result, an increase in the electrical resistance of the filament unit. The instrument is so calibrated that this change in resistance unbalances an electrical wheatstone bridge circuit, the unbalance being proportional to the concentration of the vapors in the sample atmosphere. The bridge unbalance is reflected in a voltage unbalance which activates the needle of a galvanometer and indicates the concentration of vapors.

At the present time there are several different combustible gas indicators that have been tested by the Navy and found satisfactory for use aboard naval vessels. One of these is the Explosimeter (manufactured by the Mine Safety Appliance Company). (See fig. 10-7.) The Navy-approved indicators, although manufactured by different companies, operate in accordance with the principles described above.

The indicators are capable of safely, quickly, and accurately detecting all combustible and flammable gases or vapors associated with fuel oils, gasoline, alcohol, acetone, and illuminating, or fuel gas. They are sensitive in detecting small quantities of these vapors or gases up to the lower explosive limit and beyond the upper explosive limit. They are provided with flame arresters to prevent a flash-back. The recordings are made by meters. Usually the scales

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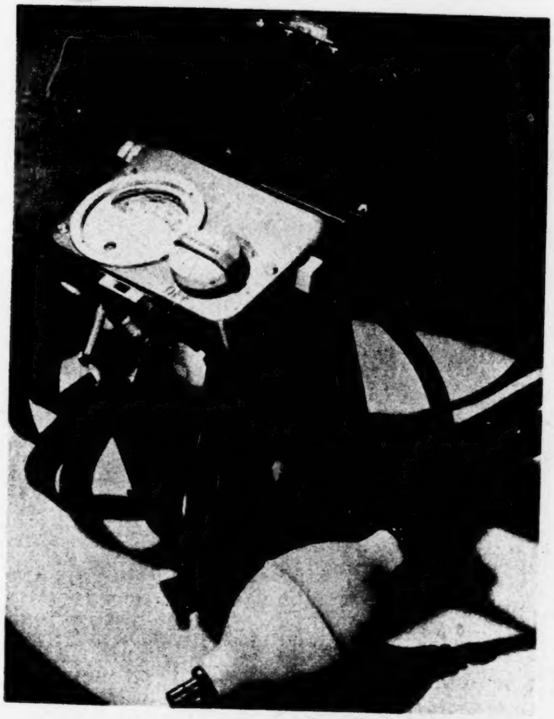


5.120
Figure 10-7.—M. S. A. Explosimeter.

are graduated so that the explosive condition of the atmosphere being tested can be read directly. However, if the combustible gas indicator is calibrated to give readings on specific gases, readings obtained with other gases may vary to some extent. Therefore, readings must be converted by means of a conversion chart.

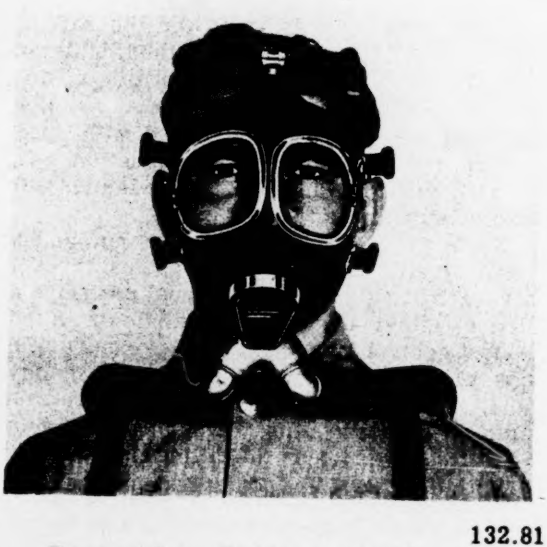
Respiratory Protection

To ensure that all nonmilitary respiratory equipment used by the Navy will afford the protection for which it is intended, only such equipment as is approved by the Bureau of Mines is used or authorized. The preparation of Navy specifications for all types of respiratory equipment takes into consideration the Brueau of Mines' requirements.

There are two main types of equipment suitable for use in the presence of toxic gases and vapors. They are: (1) fresh-air hose masks; and (2) the tank supplied air mask.

The fresh-air hose mask is designed to provide respiratory protection against oxygen-deficient atmospheres, and atmospheres that contain a high concentration of toxic gases and vapors. It can be used with a maximum of 150 feet of hose where the encumbrance of the hose line would not greatly interfere with the movement of the user. It is especially useful in entering tanks, tank cars, ship compartments, holds, and pipelines for inspections, cleaning, and repair work. The fresh-air hose mask may also be used for rescue work in recovering victims of irrespirable atmospheres.

As shown in figure 10-8 the fresh-air hose mask consists of a tight-fitting, full facepiece; breathing tubes; and a harness. The assembly also includes a noncollapsible hose line 1 inch in diameter, and hand-operated blower. The harness and hose are strong enough for retrieving the wearer in emergency, and the hose will not collapse under considerable weight. Moreover, it is so constructed that it will not kink and shut off the air supply. A dee ring is provided in the back of the safety belt harness for the attachment of a rope life line. The entire assembly of mask, hose, and blower is conveniently packed in a trunk for transporting and storage. (See fig. 10-9.) The use of a fresh-air hose mask in tank cleaning operations is mandatory. The mask is shown in figure 10-10. A more detailed explanation of limitations and proper



132.81
Figure 10-8.—Fresh air hose mask.

use of the fresh-air hose mask is contained in NavDocks P-342, Fuel Storage Tank Cleaning at the Shore Establishments (Finished Product Tanks).

The tank type air supplied mask equipment consists of a tank containing breathing air and a mask similar to the one used with the fresh-air hose line. The tanks can hold enough air to last from 15 minutes to 1 hour and are carried on the back of the wearer by a shoulder strap harness arrangement. Air is supplied to the face mask from the tank through a system of hose and regulating valves. This equipment is very useful where the wearer is required to enter hazardous areas for short intervals such as in emergency rescue work.

132.82
Figure 10-9.—Fresh air hose mask unit.

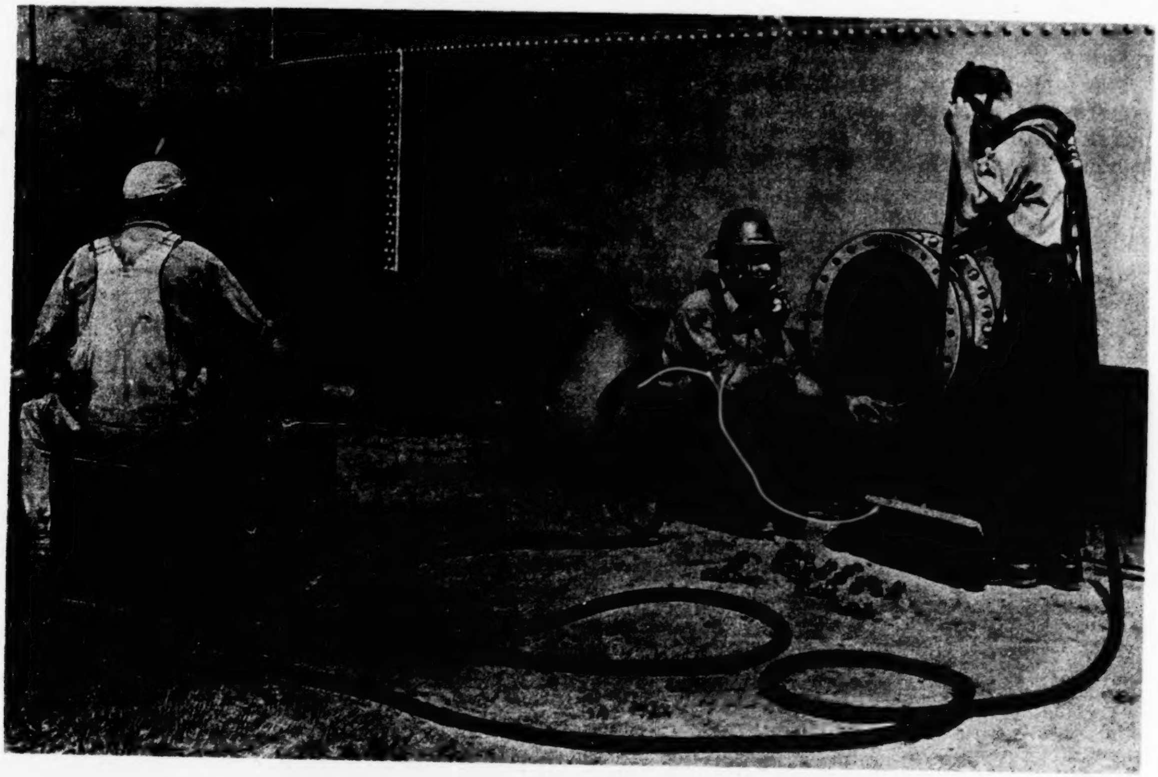


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Figure 10-10.—Use of fresh air hose mask in tank cleaning operations.

CHAPTER 11

STORAGE OF PETROLEUM PRODUCTS

Important considerations in designing and maintaining physical equipment for the storage of petroleum products whether for military or commercial use are: (1) the maintaining of the quality of the petroleum products; (2) maximum security against fire and explosion hazards; and (3) maximum security against losses resulting from evaporation and seepage. Moreover, in times of national emergency consideration must be given to the vulnerability of storage facilities to enemy attack and sabotage.

Various types of bulk storage facilities used by both the petroleum industry and the military forces are described in this chapter.

Today the Navy has a world-wide storage and distribution system which stems largely from the World War II build-up of petroleum storage facilities. This has been augmented by some additional construction of Navy-owned storage in certain instances, by leasing from commercial sources as required, and by storage made available for United States Navy use through the NATO Infrastructure construction program.

SURFACE BULK STORAGE

The principles of surface bulk storage for petroleum products are basically the same for the military forces as they are for the petroleum industry. The tanks in general commercial use have capacities of 1000, 25,000, 30,000, 55,000, 82,000, and 120,000 barrels. The tanks most commonly used by the military forces range from 25,000-gallon to 13,500-barrel capacity at air stations, and 13,500 to 150,000 barrels at fuel depots. Surface storage tanks are constructed of mild steel plates. Normally fuel storage tanks are of welded construction; advanced base tanks up to 10,000 barrels capacity are of bolted construction.

Bulk storage tanks may be classified as atmospheric storage tanks, and pressure storage tanks. The following discussion conforms to this classification.

Atmospheric Storage Tanks

Atmospheric tanks are the type most commonly employed for the storage of petroleum products. They are used for the storage of those products having vapor pressures less than that of the atmosphere under the conditions prevailing in the tanks. Atmospheric storage tanks include fixed-roof tanks and floating-roof tanks.

Fixed-roof Tanks.—A fixed-roof tank is the simplest type of atmospheric storage tank. It consists of a flat steel bottom resting directly on an earth grade or a prepared foundation, a vertical cylindrical steel shell, and a fixed roof supported by trusses or rafters. Although the roof is usually cone-shaped, it may be curved or even flat. (See figs. 11-1 and 11-2.)

A conventional tank with a fixed roof is not capable of withstanding any appreciable pressure or vacuum. Consequently, the roof must be equipped either with open vents or with venting valves designed to operate at very low pressure.

Although fixed-roof tanks are relatively inexpensive, continual vapor loss occurs as a result of breathing. (Breathing of the fixed-roof tank takes place with the increase and decrease of vapor pressure as the temperature changes, and during filling and emptying operations.) The fixed-roof tank usually operates at 1/2 oz. pressure and 1/2 oz. vacuum. As the tank is filled, the vapor above the liquid must be discharged, either to the atmosphere or to some venting or vapor collecting system.

Fixed-roof tanks are best adapted to the storage of products which have a relatively low vapor pressure, such as kerosine, fuel oil, JP-5

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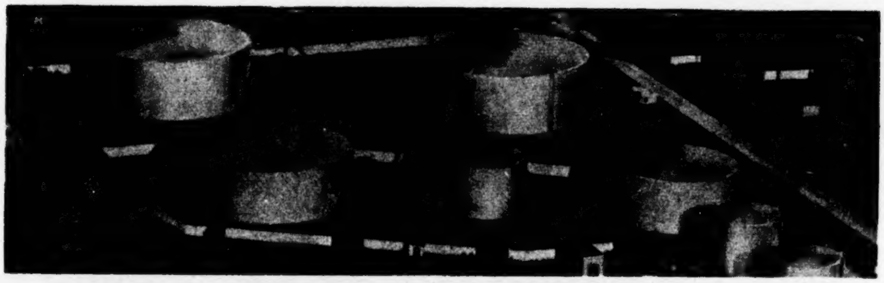

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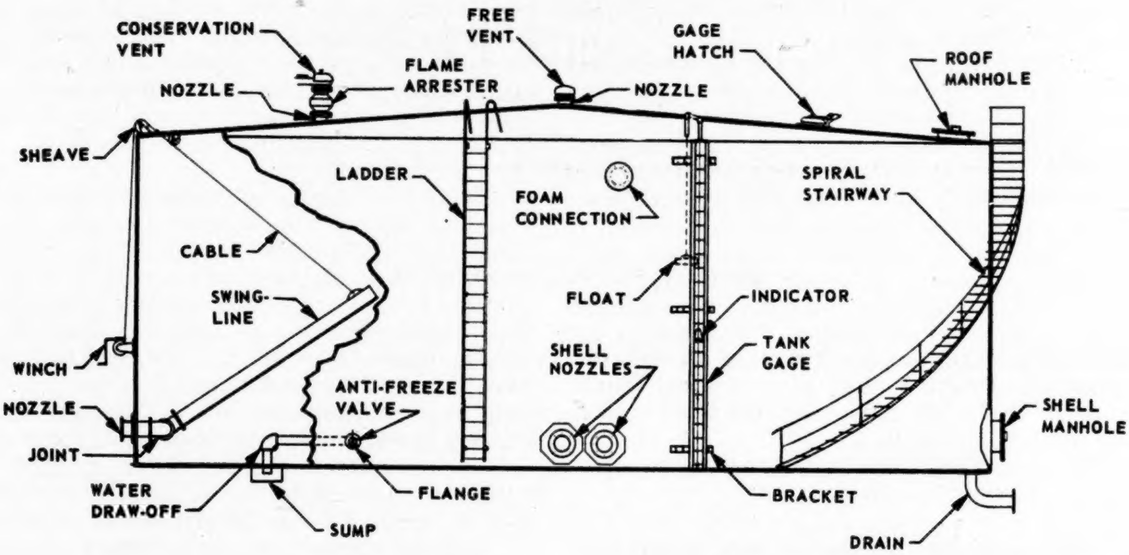
Figure 11-1.—Cone-roof tanks.


CONSERVATION VENT
FREE VENT
GAGE HATCH
ROOF MANHOLE
FLAME ARRESTER
NOZZLE
NOZZLE
SHEAVE
LADDER
FOAM CONNECTION
SPIRAL STAIRWAY
CABLE
SWING-LINE
FLOAT
INDICATOR
WINCH
SHELL NOZZLES
TANK GAGE
ANTI-FREEZE VALVE
NOZZLE
SHELL MANHOLE
JOINT
WATER DRAW-OFF
FLANGE
BRACKET
SUMP
DRAIN

132.85X

Figure 11-2.—Usual accessories and fittings on standard cone-roof tank.

jet fuel, and diesel oil. Fixed-roof tanks of 5000-barrel capacity, or more, are not usually employed for the storage of highly volatile products such as gasoline because of the attendant vapor loss. Also, other types of tanks provide greater safety factors for the storage of highly volatile products.

Floating-Roof Tanks.—Floating-roof tanks are especially adapted to the storage of fuels having vapor pressures similar to those of gasoline. They are used more commonly than any other type tank for this purpose. A floating-roof tank consists of a flat steel bottom resting directly on a prepared foundation, a vertical cylindrical

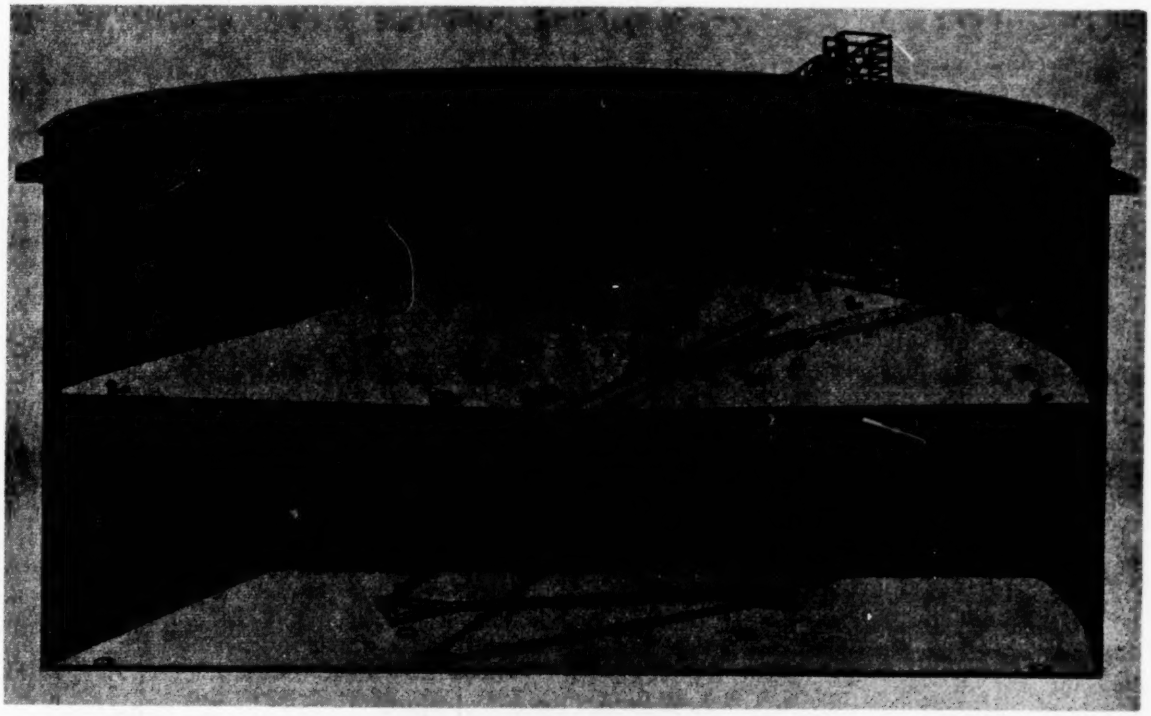


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Figure 11-3.—Floating-roof tank.

steel shell maintained circular at the top by means of a suitable wind girder; and a roof which floats on the liquid and rises and sinks as the tank is filled or emptied.

The roof may be either a center-weighted pan, a peripheral pontoon with a flexible center deck plate, or a continuous pontoon over the entire surface which, in effect, is a double-deck roof. (See fig. 11-3.) The annular space between the rim of the roof and the tank shell is closed off by a special sealing device to reduce evaporation loss around the periphery of the tank.

Since floating-roof tanks are designed to float on the liquid fuel, vapor breathing losses are practically eliminated; corrosion, which is caused by the presence of air, is almost entirely eliminated; fire hazard is materially reduced.

Although the floating-roof tank eliminates filling loss, it is susceptible to some minor standing loss—primarily as a result of the action of the wind which tends to take vapors out of the narrow space between the seal and the tank shell. Therefore, floating-roof tanks can be most economically used when throughput is high and tank turnovers rapid.

Pressure Storage Tanks

Pressure storage is used for the storage of products having vapor pressure sufficiently high to cause boiling at atmospheric pressure. Such boiling, if permitted to continue for any appreciable time, results in serious loss of product. The boiling temperature of a liquid can be raised by increasing the pressure acting upon its surface. It follows then, that boiling losses can be prevented by increasing the pressure just above the vapor pressure of the liquid. Therefore, pressure tanks are used for the storage of products such as natural gasoline and liquefied petroleum gases, as well as some other volatile liquids such as anhydrous ammonia.

Pressure tanks are of various shapes, including spheres, spheroids, hemispheroids, and cylinders.

Spheres.—Tanks in the shape of spheres are used extensively for storing liquids requiring storage at relatively high pressures. When subjected to uniform internal pressure, the shell is stressed equally in all directions. Tanks which are shaped like spheres are usually supported by a number of tubular columns attached to the shell.

Spheroids and Hemispheroids.—Spheroids and hemispheroids also may be used for the storage of volatile liquids but are especially well adapted for the storage of motor and natural gasolines. They are designed to prevent excessive evaporation losses which occur when such products are placed in conventional tanks. Spheroid tanks are used for low-pressure storage of large quantities of petroleum products. Hemispheroids are used for the storage of smaller quantities of petroleum products requiring low-pressure storage.

Cylinders.—Cylindrical pressure tanks are used for the storage of propane and similar petroleum products. Cylinders are usually limited in size to approximately 10 to 12 feet in diameter and to approximately 40 feet in length. They may be installed either vertically or horizontally.

UNDERGROUND BULK STORAGE

Since above-ground tanks are extremely vulnerable to air attack, the Navy, prior to World War II, conducted studies to determine the best method of solving the problem. Several possibilities were investigated including: (1) placing steel tanks underground to the point of concealment only; (2) constructing prestressed circular, reinforced concrete tanks and concealing them by cut-and-cover methods; (3) constructing steel-lined concrete vaults; and (4) constructing underground steel tanks.

It was decided that vertical-type cylindrical domed vaults of concrete encased steel afforded the most practical type of storage. It was concluded that such construction would make the tanks relatively bomb proof. Duplicate piping and pumping equipment were recommended. The cost of this type of storage was estimated to be too high for adoption as a standard, but was considered necessary to safeguard supplies of vital petroleum products at certain strategic locations.

Although some bomb-proof underground steel tanks were constructed, the majority of underground storage tanks used by the military forces were of prestressed concrete. In prestressed concrete tanks, circular steel rods are installed to hold the concrete side walls in compression, to prevent cracks, and to keep vertical construction joints tight.

Coatings and Lining Systems for Concrete Tanks

Prior to and during the early years of World War II, the need was great to divert steel into vital and essential uses. The wide spread construction of prestressed concrete tanks for the storage of petroleum fuels greatly reduced the requirements for steel. Several hundred such tanks were constructed throughout the armed services for all types of petroleum fuels.

When used for burner fuels such as Navy Special and Grades 5 or 6, the interior surfaces of such tanks are usually treated with a solution of sodium silicate to fill the interstices of the concrete. Tanks so treated are tight and relatively chemically inert to the more dense petroleum fuels.

The use of prestressed concrete tanks for the storage of all gasolines and jet fuels involves far more penetrating liquids with many additives for end objectives. Some of the additives which might be encountered in such fuels are gum, oxidation and corrosion inhibitors, combustion improvers, and anti-icing additives. Many of these additives would react with the alkaline concrete. Moreover, minor cracks in the concrete would result in serious leakage. Consequently, for all gasolines and jet fuel storage, concrete tanks must be provided with an interior lining or coating system which acts as a chemically inert barrier between fuel and concrete. Such a system should possess the following properties: Adhesive and cohesive strength, chemical inertness, no catalytic effect, elongation characteristics, relative impermeability, favorable cost and applicability.

In the early days of concrete tanks, lining systems were developed by the use of organic polydisulfides. Coatings made of these materials remained stable over a period of years in most cases.

Extensive research has led to two vastly improved coating systems for the interior surfaces of concrete tanks. These coating systems are described in NavDocks Specification 47Y as Types 51 and 53. Type 51 consists of undercoats of a latex with fabric reinforcement over which is applied multiple coats of saran lacquer. Type 53 consists of a blend of latexes and is similarly applied.

These lining systems have been subjected to extensive use and techniques are available for applying to fresh new concrete as well as to oil impregnated concrete surfaces. It is desirable to apply test patches on the surfaces to be coated for any specific tank.

Coating and Lining Systems for Steel Tanks

Interior coating systems for steel tanks serve to prevent corrosion of the metal surfaces and ultimate loss of the tank, and to prevent contamination of the stored fuel by products of tank corrosion such as metal oxides, hydrates, or salts.

As a general practice, steel tanks which are used for the storage of diesel fuel and heavier grades of fuel do not require interior coatings. The heavier and more viscous fractions of these fuels adhere to the metal surfaces providing for protection of the metal surfaces. The exception of this is water which settles to the bottom of tanks and is not removed. Water bottoms, either fresh or salt, will promote corrosion of the steel.

The settling time of solids and water in JP-5 is the longest of all aircraft fuels and the need for fuel cleanliness is great. Ready issue tanks for this grade of fuel should be entirely coated internally. Other tanks for gasolines or light fraction jet fuels need not be entirely coated. The interior surfaces of such tank bottoms and 2 feet up the sides should be provided with an appropriate coating to preclude corrosion from water which settles out of the product.

Interior coatings for steel tanks which have been tested and approved as to formulation by the Navy include polyurethanes, modified epoxides, vinyl type resins, and furan resins. The polyurethanes have demonstrated exceptional chemical resistance and toughness.

Exterior coatings for steel tanks differ greatly in surface and subsurface tanks. Underground steel tanks should be externally coated with an approved coal tar primer and enamel. This coating system is described in NavDocks Publication 34Y. Consideration also must be given to the corrosive effect of soil on the tank. Where corrosive conditions are severe, cathodic protection is required. Cathodic protection consists of making the electrical potential of the walls of the tank to be protected lower than that of the surrouding soil. The metal is thus made a cathode instead of an anode. Electrochemical corrosion occurs at the anode when two dissimilar metals are in contact in the presence of an electrolyte. The metal of higher potential will become the anode, tend to go into solution in the electrolyte, and therefore corrode. The tank is protected by making it a cathode since corrosion occurs only at the anode. It has been found that all usual forms of corrosion are prevented when the cathode protection makes the metal wall or other metallic structure 0.25 to 0.3 volt negative with respect to the soil or liquid surrounding the tank.

The exterior surfaces of above ground tanks should be painted for general appearance and to preclude atmospheric corrosion. Such tanks in the service of high vapor pressure products should be painted with materials which result in a high reflection coefficient for solar radiation to minimize vapor losses. Applicable specifications should always be used for both materials and applications.

Spacing of Tanks

In order to minimize the effect of bombing or strafing against tanks, the location of the tanks is staggered, where possible. As a further protection against bombing, the layout of large developments is separated into two or more subgroups. Generally, not more than four tanks are placed in a row; tanks are spaced at least one tank diameter apart, and adjacent rows of tanks are spaced at least 150 feet apart.

STORAGE OF PACKAGED PRODUCTS

Although the largest percentage of military petroleum products is stored in bulk and dispensed by bulk handling equipment, military operations may require the handling of these products in relatively small containers commonly referred to as packages. In the storage of packaged products, consideration should be given to type of product, type and condition of containers, availability of space and equipment, natural and man-made environment, and costs. The following prescribed procedures are recommended; for more detail refer to Military Standardization Handbook Petroleum Operations, MIL-HDBK-201A.

Types of Packages

55-Gallon Drums.—For many years, the 55-gallon drum has been used for storing and transporting packaged gas lines. Drums used by the military forces are 16-gage or 18-gage containers having bungs in the end for filling and emptying. When filled, each weighs approximately 400 pounds.

Other Containers.—Many other petroleum products, such as lubricating oils, gear lubricants, and lubricating greases are handled in cans, drums, pails, and other packages, ranging from 2 ounces to 500 pounds, depending upon the requirements and intended use of the products.

Can, Gasoline, Military 5-Gallon.—These cans are used extensively by the military forces to supply gasoline to ground units in the field. It has a large 2-inch screw-type closure from which gasoline may be poured by the use of a flexible nozzle.

Additional Information.—For information concerning dimensions, weights and cube of various packaging containers, refer to Military Standardization Handbook, Conversion Factors and Logistic Data for Petroleum Planning, MIL-HDBK-210.

All containers used for storing petroleum are required to be clearly marked with the contents and date for the following purposes:

1. To identify products so that proper products may be issued for required use.
2. To segregate stocks so that, in any petroleum storage area, the products can be readily located and rapidly issued.
3. To ensure priority of issue so that stocks which have been in storage for the greatest length of time can be used first, thereby avoiding deterioration.

Refer to Military Standard-Packaging, Packing, and Marking of Petroleum and Related Products, MIL-STD-290 for instructions as to standard uniform markings. This standard also provides standard packaging and packing methods.

Storage of Drummed Products

The type product and the facilities available will determine whether inside or outside storage is appropriate. Whenever possible, lube oils and greases are stored indoors. Fuels, including used fuel containers, should be stored out of doors away from buildings. Empty fuel containers which are new or have been reconditioned since last containing fuel should be stored indoors whenever possible.

Outdoor Storage of Drums

A level site should be selected that is not in or adjacent to a congested area, with the contour of terrain being such that an immediate run-off of surface water is possible through a system of open ditches. Drainage into any sewer system is prohibited. An adequate supply of water for firefighting purposes should be taken into consideration in the selection of this site. The drum storage area should be located or arranged so that escaping flammable vapors normally flow away from operational areas and sources of ignition. Gasoline vapors are heavier than air and tend to lie in a stratum less than 4 feet above grade and flow toward lower ground much as liquid flows to a lower level. The drums should be stored horizontally on suitable dunnage, in double rows, butt to butt with liquid pressure on the closures. Normally, low flash products should not be stored in rows more than 35 drums long nor more than 3 tiers high. For the storage of high flash products the quantity of drums stored in a tier may be doubled.

Covered Storage

Clearances of at least 100 feet should be maintained between warehouses or from other buildings, spark producing equipment, and fires of any kind. Warehouses should be constructed of fire resistant materials and only the ground floor used for storage of packaged products. Adequate firefighting equipment should be available. Storage areas in each warehouse should be planned so that products can be segregated into sections with adequate aisles and curbing placed around each section to prevent the spread of spilled liquids to other sections of the warehouse. The primary objective in the arrangement of containers is to store the maximum quantities of products in a limited space while maintaining fire protection and providing ease and safety in handling the containers.

Storage of Products in 5-Gallon Military Gasoline Containers

Filled 5-gallon gasoline containers are normally stored in outdoor storage areas. To conserve space and to provide stability of stacks, filled 5-gallon gasoline cans should be stacked in pyramids, normally 4 tiers high, unless cans are palletized.

Storage of Packaged Lubricants and Greases

All packaged lubricants and greases in packages other than 55-gallon drums should be under covered storage. If covered storage is not available lubricating oils and greases may be stored outdoors provided the containers are protected from water, heat, and sun by fire retardant tarpaulins. Storage should be such as to provide for segregation of the products into sections. The lubricants should be stacked on pallets or adequate dunnage.

Storage of Empty Containers

Empty containers should be protected from damage by careless handling, and from contamination of interior by dirt, water, and other extraneous matter. Tightly closed containers will retard interior corrosion to a great degree. New or reconditioned containers received for storage will have no product markings thereon. These containers should be inspected periodically to ensure their usability at all times. Containers evidencing interior or exterior corrosion should be removed for possible reclamation. Empty containers previously containing products should be treated as explosion hazards and handled accordingly prior to reconditioning. Closures should be tightly closed, as an open bung or vent emits hazardous vapors for some time after removal of the product. Economically reparable containers may be reconditioned. Empty drums and cans may be stacked by any of the methods prescribed for filled drums and cans but without height limitations.

CHAPTER 12

TRANSPORTATION OF PETROLEUM PRODUCTS

Petroleum products packaged in drums, cylinders, or small containers are moved by rail as freight and by water as general cargo; bulk products are transported by pipeline, tank car, tank truck, barge, or tanker. (See fig. 12-1.) Because most military petroleum products are transported in bulk, and because the problems of bulk transportation are peculiar to petroleum, this chapter is concerned only with bulk transportation.

Bulk petroleum cargoes are frequently referred to as clean or black. Clean cargoes include such products as aviation and motor gasolines, diesel oils, jet fuels, kerosines, and lubricating oils. Black cargoes include crude oil and bunkering fuels. Tankers and other means of transportation for bulk petroleum are commonly designated as clean or black, according to the product last carried.

Pipelines, tank cars, tank trucks, and tank barges are discussed in this chapter. Because of the importance of tankers to the Navy, a separate chapter is devoted to the subject. (See ch. 13.)

PIPELINES

Pipelines in the United States

The transportation of crude petroleum and petroleum products by pipelines occupies a unique position in the Nation's transportation system.

The importance of pipelines in the transportation of petroleum products was demonstrated in World War II when it became imperative to rush large volumes of gasolines and fuel oils to ports and industrial centers. Prior to the war, more than 40 percent of all the petroleum products used in the entire country went to the eastern coastal area. When the ports of the east coast became the closest supply source for the African and European battle zones, the demand for refined products increased tremendously. Previously, all but an insignificant fraction of the petroleum products had been delivered to this area by tanker, but tanker deliveries were considerably decreased by enemy submarine action.

To correct deficiencies in transportation, pipelines were mobilized in an all-out effort to meet the demands. The supply problem could not have been surmounted by the already greatly overburdened rail transportation. In mobilizing the pipeline system, the country's few existing pipelines were relocated and linked together, so that it was possible to deliver more than 160,000 barrels of petroleum products to the east coast every 24 hours. This represented nearly a 400 percent increase over the volume carried by pipelines before the war. To accomplish this, about 3000 miles of old pipe were dug up, salvaged and relocated. More than 300 miles of natural gaslines were converted to oil service. The direction of flow of about 3000 miles of existing line was reversed.

As shown in figure 12-2, in 1941, 95 percent of the petroleum deliveries to the east coast were by tanker; in 1945, only 22 percent of the deliveries were by tanker, and 40 percent by pipelines.

Strategic Importance of Military Pipelines

As a means of transportation at the battle front, pipelines have distinct advantages over other methods of transportation. As land forces advance, supply lines must be extended. Supplies such as food and ammunition are carried by truck, railroad, or aircraft. Convoys congest the normal transportation facilities of highways. The use of pipelines to move vital petroleum products helps to relieve the congestion of other means of transportation and thus facilitates the movement of all classes of supplies. Pipelines are not limited to fixed or cleared routes, but

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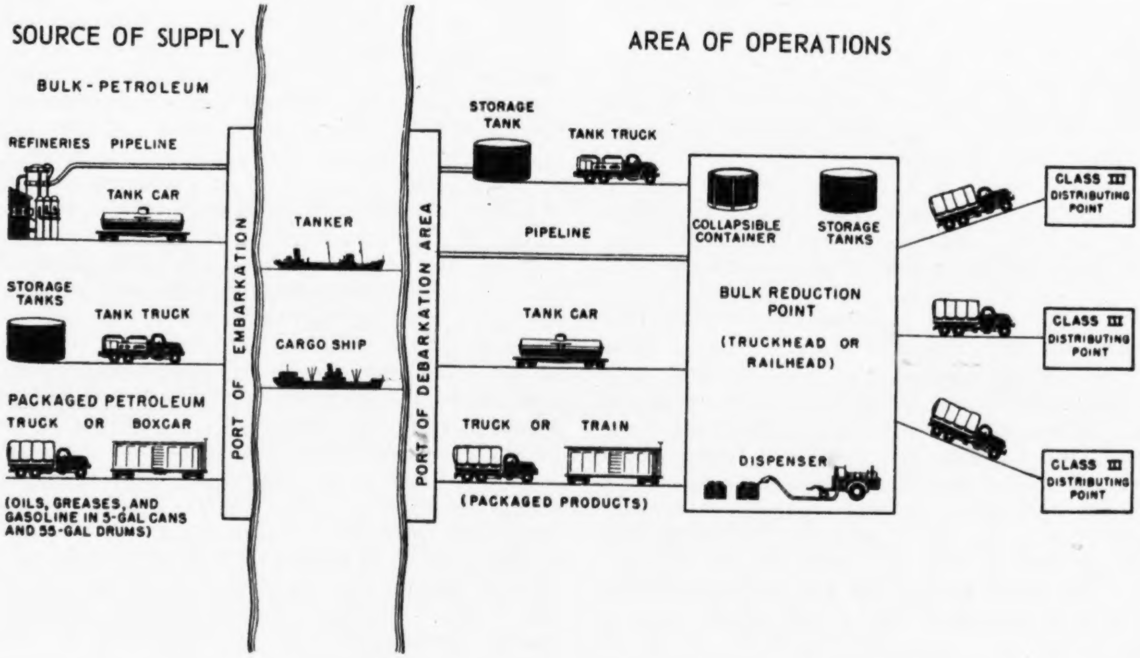
SOURCE OF SUPPLY
BULK-PETROLEUM
REFINERIES
PIPELINE
TANK CAR
STORAGE TANKS
TANK TRUCK
PACKAGED PETROLEUM
TRUCK OR BOXCAR
(OILS, GREASES, AND GASOLINE IN 5-GAL CANS AND 55-GAL DRUMS)
PORT OF EMBARKATION
TANKER
CARGO SHIP
PORT OF DEBARKATION AREA
AREA OF OPERATIONS
STORAGE TANK
TANK TRUCK
PIPELINE
TANK CAR
TRUCK OR TRAIN
(PACKAGED PRODUCTS)
COLLAPSIBLE CONTAINER
STORAGE TANKS
BULK REDUCTION POINT
(TRUCKHEAD OR RAILHEAD)
DISPENSER
CLASS III DISTRIBUTING POINT
CLASS III DISTRIBUTING POINT
CLASS III DISTRIBUTING POINT

132.87

Figure 12-1.—Flow of petroleum products to area of operations.

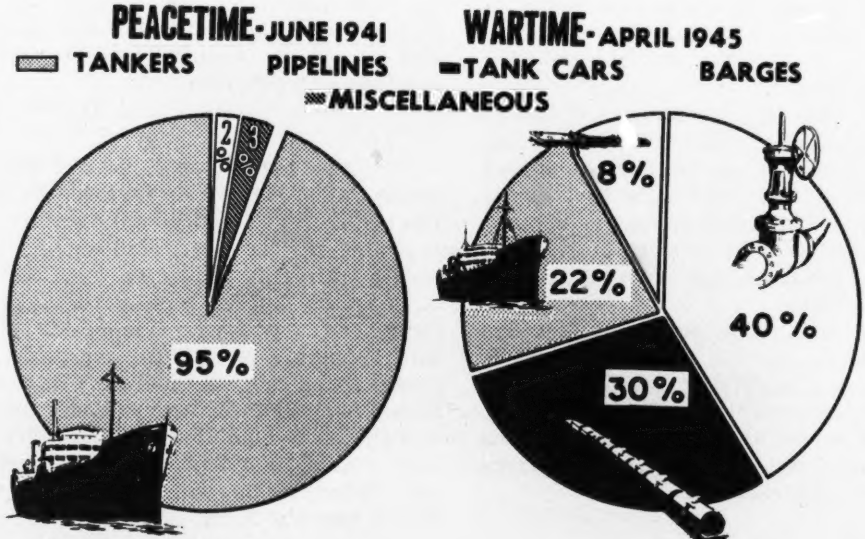

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Figure 12-2.—Petroleum deliveries to the east coast, 1941, 1945.

may be laid crosscountry, over rough terrain, through woods, across waterways, and underwater. In addition, pipeline delivery is more reliable than any other means of transportation as it is least affected by climatic hazards, and if properly routed and concealed is less vulnerable to enemy action.

During World War II, the Navy, faced with the problem of transporting fuels from refineries in the Caribbean to the Pacific Theater, built tank farms at Colon, on the Atlantic side of the Panama Canal, and at Balboa, on the Pacific side. These two tank farms were connected by four pipelines. Two 20-inch lines carried Navy Special fuel; one 12-inch line carried gasoline; a 10-inch line carried diesel fuel. Slow tankers were put on the tank from Aruba and Curacao for discharge into the tank farm at Colon. The oil was then pumped across Panama and loaded into fast tankers. This method freed the Canal for other vital war shipping and speeded up delivery of oil to the Pacific. Also, by this method the Pacific Fleet would have been provided with a fuel lifeline even if the Canal had been destroyed or damaged.

In the European theater, various military projects were undertaken to ease the storage and distribution problems, and in particular, to minimize the dependence on tankers. For example, to ensure the adequacy of the petroleum supply in France, following the establishment of beachheads, 20 complete lines (700 miles of pipe) were laid under the English Channel. This operation, known as PLUTO, was of invaluable help to the allied cause.

Since World War II, the increased use of pipelines has proven very effective for the distribution of petroleum products. Many pipelines have been installed for receiving fuel direct from refineries and distribution points. Advance base pipeline systems to support amphibious operations and forward areas are available for contingency operations.

An extensive storage and pipeline system has been constructed in various NATO countries to provide a system of supplying petroleum products for land and air operations. This immensely flexible system would enable the Allied forces to take both immediate and sustained retaliatory action against an aggressor.

Pipeline Systems

For protection, pipelines are usually laid from 18 inches to 38 inches underground. Unless there is a more or less continuous downward slope, oil will not flow through pipelines unaided. Therefore, pumping (booster) stations must be installed at intervals. (See fig. 12-3.) A pumping or booster station consists of suitable storage tanks, motive power, and pumps for pumping the oil along the line. The frequency of booster pump stations required in a fuel transmission pipeline is influenced primarily by the topography of the country through which the line passes, the viscosity of the fluid being pumped, the rate of flow of the fluid, and the safe working pressure to which the transmission line may be subjected. The average distance between stations is 40 miles, but in rugged, hilly country, the stations may be spaced every 15 to 20 miles; and in flat country, the distance may be 60 miles or more. Telephone equipment is usually installed at pumping stations, with portable sets at desired points along the pipeline route. Flow control equipment is shown in figure 12-4.

Seamless and electrically welded pipe, capable of withstanding 1200-pound operating pressure, is in general use today. Commercially, lengths of pipe are 30- to 40-feet long. For military portable service, light weight pipes from 4 to 6 inches in diameter are commonly used. In this case, the lengths of pipe are standardized to 20-foot lengths.

Pipelines, when laid underground are normally coated with a coal tar base enamel, or other protective substance, and wrapped with a protective material. This is done to protect the pipe from the corrosive elements of the earth in which they are buried.

Capacity

The capacity of petroleum pipelines is determined by the size of the pipe, the physical characteristics of the oil, temperature, pumping pressure on the line, and topography of the country through which the pipelines are laid.

A 6-inch pipeline passing through fairly level country at a moderate temperature, and having booster pumps at 40-mile intervals with 1000 pounds pressure on the line will deliver about 15,000 barrels in 24 hours. Under the same conditions, an 8-inch line with 1,000 pounds pressure will deliver 25,000 barrels; and a 10-inch line under 1000 pounds pressure will handle 47,500 barrels of oil.

Laying Pipelines

In laying pipelines, consideration must be given to distances to be covered, elevations,

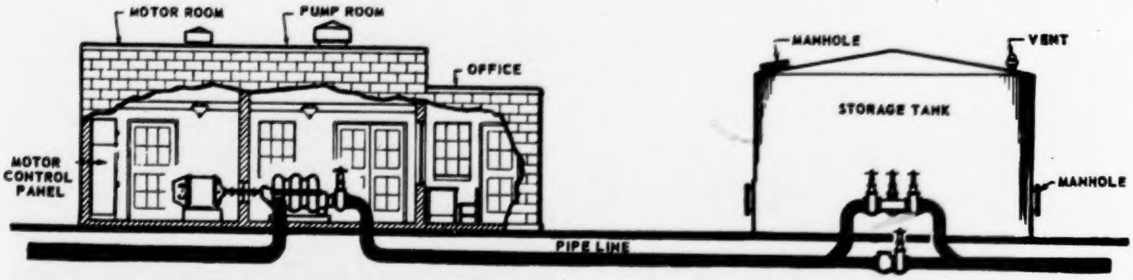

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Figure 12-3.—Pipeline pumping station.

topography traversed, the condition of the soil, and crossings—such as those across streams—which must be made.

If no natural depressions occur, a trench is excavated. The pipe is then laid out, and couplings installed. The quick-type groove couplings furnished for military pipelines are easily installed and pulled tight by two-man teams. With several teams installing and tightening couplings, the line is completed as rapidly as the pipe can be laid. After pipes have been joined, they are lowered into the trench. The trench may or may not be filled in.

After lines are laid, they must be tested. First, a scraping device, known as a go-devil, is forced by flow of liquid through the line to ensure that there are no obstructions. Water is then pumped through the line at a pressure higher than that to be used for moving petroleum products, in order to test for leaks in piping and for defective joints.

Camouflaging Pipelines

In planning the course of pipelines in combat areas, advantage is taken of all possible natural growth. All natural depressions in the earth, such as roadside ditches, are utilized. If pipeline trenches are not filled in, dirt is banked along both sides of the pipe to eliminate pipe shadow, or the entire line is camouflaged by painting. Tanks and pumps used in connection with pipelines are frequently set in recessed pits, installed under natural cover, or disguised by the use of garnished nets.

Offshore Pipelines

Pipelines may be laid on the ocean bed so that tankers can load and discharge offshore. In this way, tankers moored at a sea berth can receive and discharge their cargo directly from and to tanks on shore.

Several methods for installing submerged lines are feasible. The method used depends upon the type of bottom present, the personnel and equipment available, and upon wave, tide, and wind conditions.

In one method, wooden ramp is laid on the beach either at right angles to the shore line or in the direction the offshore line is to take. The ramp is constructed of two lines of timbers made fast with stakes, as shown in figure 12-5. The timbers support rollers made of 2- or 3-inch pipe held in place by wooden blocks. The end of the ramp is allowed to extend to low water so that sections of pipe pushed from the ramp will float. The ramp extends to a point on the beach where it is easy to place sections of pipe on it.

A hose adapter is welded on the end of the first pipe and a blind flange bolted on for water tightness. Additional lengths of pipe are then welded on and pushed along the ramp into the water, continuing until the pipe is of sufficient length to reach the proper point.

Some pipes require an occasional oil drum for support but others float without support. The end of the line can be guided by a small skiff in a calm sea. Under more adverse conditions, an anchor and buoy can be placed in line with the pipe and a connection can be made to pull the end in the right direction.

In the next step, the cargo hose, with ship end connections, is taken out on a raft and connected to the end of the floating pipeline and to a marker buoy. The weight of the pipe after it is filled with oil may be sufficient to hold it in position. If not, anchors are used. These consist of a pair of fabricated concrete blocks with 1-inch iron

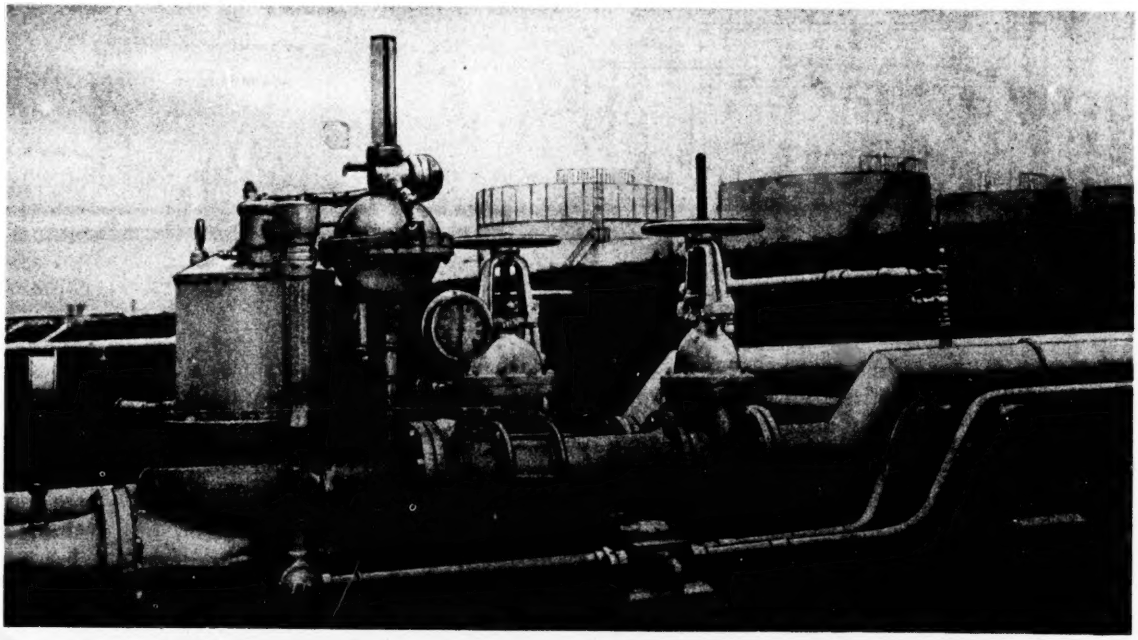

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Figure 12-4.—Flow control equipment.

132.91

Figure 12-5.—Installing offshore pipelines.

stirrups cast into the concrete to provide connections for a 1/2-inch chain that is used to tie down the pipes.

The general layout of fueling connections is set up so that the lines fan out to present the connections in line with the side of a ship moored in the fueling berth. The direction and location of the fueling berth will depend on the prevailing winds and currents. If fuel oil, diesel oil, and gasoline lines are all installed, the fuel oil line is usually located in the center, with the diesel oil line toward the moorings or stern, and the gasoline line toward the bow because tankers usually carry their gasoline in the forward tanks and their diesel oil aft. Submerged pipelines are kept filled with petroleum products. When tankers are ready to load, the product to be loaded is pumped into the tanks by a pumping station at the shore end.

Prevention of Product Commingling

Three precautions are necessary to prevent the commingling of petroleum products moved through pipelines:

1. Before pipeline transfer is started, it must be determined whether the product already in the line is satisfactory for inclusion in the cargo to be moved.
2. Multi-product pipelines must be properly flushed and cleaned.

3. Proper blinding-off of connection lines and correct valve control must be ensured during transfer.

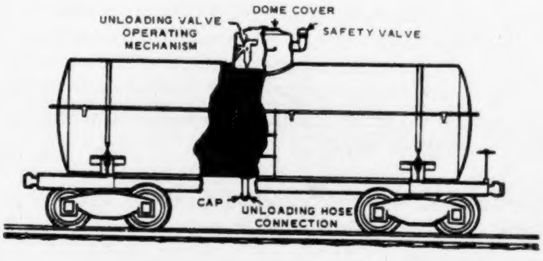
TANK CARS

Tank cars are used primarily for land transportation of finished products where pipelines and waterways do not exist. Because this method of transportation is relatively costly, it is used by the petroleum industry less extensively than other methods of transportation. During World War II, however, when reliance had to be placed on overland movement of petroleum, tank cars were pressed into service. Tank cars, usually used for short-haul service, were brought from all corners of the Nation and were placed in long-haul service to the east coast and later to the west coast. Thus, the tank car has been termed the trouble-shooter of petroleum transportation facilities in times of adverse weather conditions, pipeline limitations, and other contingencies.

Physical Features

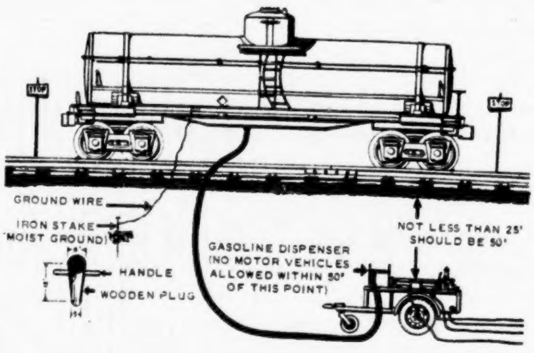
A tank car is a metal cylindrical tank mounted on an underframe. This underframe is fitted with axles and wheels that run on railroad rails. (See fig. 12-6.) Tank cars vary in size and detail of design but can be readily recognized, not only because of their cylindrical shapes, but because of their domes or turrets. Capacities range from 6,000 to 14,000 gallons.

Bulk cargo is charged to the tank through a connection on the turret. The turret also provides space for expansion of oil and for vapors which may accumulate. A blow-off valve in the turret provides for escape of such vapors in case pressure becomes excessive. Cargoes are usually discharged through an outlet at the bottom of the tank, although they may be discharged through the dome. (See figs. 12-7 and 12-8.)


DOME COVER
UNLOADING VALVE OPERATING MECHANISM
SAFETY VALVE
CAP
UNLOADING HOSE CONNECTION

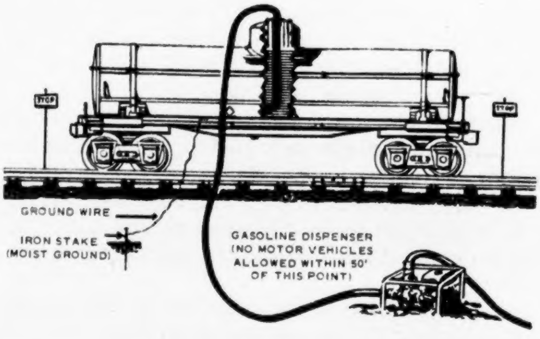
87.39X

Figure 12-6.—Tank car.


STOP
STOP
GROUND WIRE
IRON STAKE (MOIST GROUND)
HANDLE
WOODEN PLUG
GASOLINE DISPENSER (NO MOTOR VEHICLES ALLOWED WITHIN 50' OF THIS POINT)
NOT LESS THAN 25' SHOULD BE 50'

87.40

Figure 12-7.—Unloading tank car through the bottom.


STOP
STOP
GROUND WIRE
IRON STAKE (MOIST GROUND)
GASOLINE DISPENSER (NO MOTOR VEHICLES ALLOWED WITHIN 50' OF THIS POINT)

87.41

Figure 12-8.—Unloading tank car through the dome.

Various modifications of the tank car design have been evolved to suit the needs of varied types of petroleum and petroleum products. Some tank cars are designed with steam heating coils for reducing the viscosity of products such as asphalts and some fuel oils. Compartmented cars are designed to carry two or three grades of products simultaneously. Insulated cars are used for shipping very volatile petroleum products. The tanks of these cars are covered with an insulating material (hair, felt, or cork) and have an additional outside sheathing of metal.

Hazards of Loading Tank Cars (Gasoline)

The greatest potential danger in loading gasoline or other volatile oils into tank cars is from fire resulting from the release and possible ignition of flammable vapors. However, fires at tank car loading racks are not the greatest source of accidents. The car loader is exposed to the danger of slipping and falling, to strains and asphyxiation, and it is from these causes that most accidents at tank car racks occur.

Transfer Operations

When oil is loaded into tank cars in large quantities, loading racks are employed. A pipeline is constructed, paralleling the railroad tracks at one side, and elevated a few feet above the tops of the turrets. Connections are provided at intervals, conforming with the standard length of cars. In this way, an entire train of cars can be loaded simultaneously.

To unload bulk petroleum products from tank cars, the train crew must spot the car accurately, bringing the dome opposite the unloading connection in such a manner that the connection will not be strained. If the car is not spotted at the proper location, it may be moved to the desired spot by use of a sampson bar.

When the tank car has been properly spotted, the following steps are taken, preparatory to making unloading connections:

1. The brakes of the car are set and the wheels blocked so that the car cannot move and break connections during the unloading operations.
2. Signs bearing the words STOP—TANK CAR CONNECTED—are placed midway between the rails at the open end or ends of the tank on which the car is spotted.
3. The storage tank into which the tank car is to be unloaded is gaged to make sure that it will hold the quantity intended for it.
4. Shipping numbers are checked to ensure that the proper product is being delivered.
5. Grounding connections are made.

TANK TRUCKS

Although truck transportation of bulk petroleum products was well established by the advent of World War II, it received a tremendous stimulus during the war as means were sought to free tank cars for long distance movement to replace ocean tankers.

From war experience, shippers realized that tank trucks had a definite economic place in short-haul movements for the following reasons:

1. Faster turn-around time is possible.
2. Less expensive loading installations are required for truck transport than for other means of transportation.
3. Delivery by truck transports can be made direct to large consumers, by-passing bulk plants, and thus eliminating double handling.
4. Truck transportation provides greater flexibility because movements do not have to be planned in accordance with train schedules.

A tank truck loading platform at a commercial gasoline storage terminal is shown in figure 12-9.

In military operations, highway transportation is characterized by its great flexibility and adaptability to changing tactical conditions. Thus, in transporting petroleum products in advanced areas, the motor vehicle provides a very adequate solution to the transportation problem presented when neither pipelines nor railroads are available, or where tactical conditions do not warrant the use of these means.

Physical Features

There are various types and sizes of tank trucks and trailers used to transport petroleum products. One type is shown in figure 12-10. Commercially, 6000 to 8500-gallon tank trucks are used extensively although larger units are in use in some parts of the country. At military stations, 750-gallon tank trucks and 3500-gallon semitrailers are commonly used as refuelers.

Safety in Transfer Operations

In transferring gasoline to or from tank trucks, it is of special importance that all safety measures be observed. The same general procedure is followed as in the transfer of gasoline to or from tank cars. The American Petroleum Institute has issued an accident-prevention manual on Safe Transportation of Petroleum Products by Tank Truck (Accident-Prevention Manual No. 11, March 1942).

Precautions Against Product Contamination (Tank Cars and Tank Trucks)

Precautions to prevent product contamination must be taken in loading both tank cars and tank

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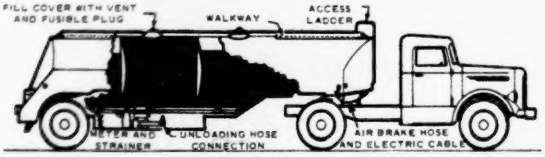
Figure 12-9.—Tank truck loading platform at a commercial gasoline storage terminal.


FILL COVER WITH VENT AND FUSIBLE PLUG
WALKWAY
ACCESS LADDER
METER AND STRAINER
UNLOADING HOSE CONNECTION
AIR BRAKE HOSE AND ELECTRIC CABLE

87.38X

Figure 12-10.—Tank truck.

trucks. Improper interior condition of tank cars and tank trucks is a primary source of contamination when petroleum products are transported in such containers. Serious conditions may result: (1) when a container has previously transported a product other than that to be loaded and has not been emptied completely; (2) when a previously transported product is of a nonevaporating nature and adheres to the walls or is absorbed in the scale formation; and (3) when an appreciable quantity of loose or loosely adhering scale is present.

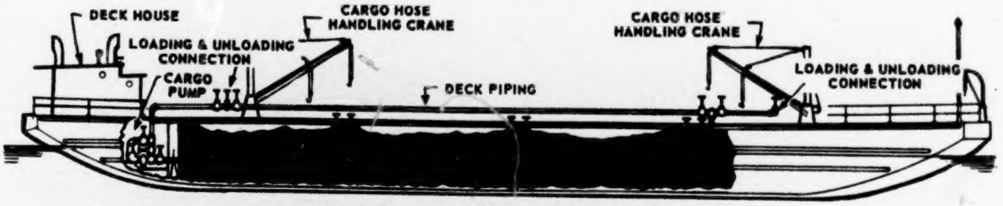
Each tank car and tank truck must be inspected by a qualified individual, particularly the condition of the interior prior to loading. When inspection reveals the interior of the container is not in a condition which is satisfactory for the product to be loaded, the tank car or tank truck is rejected and submitted to cleaning or placed in service for a product for which it is suitable.

Attention must also be given to outlet and safety valves to ensure that they are properly seated and in operable condition. In the case of tank trucks, it must be assured that the manifold has been completely drained of the product which it has previously contained.

TANK BARGES

Tank barges used to transport petroleum short distances or to provide temporary or semipermanent storage. They may be towed or self-propelled. (See fig. 12-11.)

The average barge has a capacity of from 6000 to 10,000 barrels. Some barges are constructed to handle cargoes of two or more types of petroleum products. Cargoes of petroleum products, except lubricating oils, are loaded through pipelines in the conventional manner. A sample is taken for identification tests upon starting to load and another sample is taken when the barge is approximately three-fourths loaded. The same general procedure must be followed for the proper control of barge operations as is followed with tanker cargoes. (See ch. 13.)


DECK HOUSE
CARGO HOSE HANDLING CRANE
LOADING & UNLOADING CONNECTION
CARGO PUMP
DECK PIPING
CARGO HOSE HANDLING CRANE
LOADING & UNLOADING CONNECTION

132.96X

Figure 12-11.—Tank barge.

Lubricating oils are loaded through special pipelines in order to avoid contamination.

The following are the principal uses of tank barges:

1. For bunkering vessels which are docked at some points where bunkers are not available.
2. For transporting petroleum products to or from terminals where bunker operations of ocean-going vessels are limited by the depth of water.
3. For inter-refinery movements of petroleum products where water suitable for barge navigation is available and there are no pipe lines between the refineries.
4. For topping off partially loaded ocean tankers where the expense of docking the tanker would be excessive or docking would be impossible due to the depth of the water, tide, and wind.
5. For transportation of petroleum products between points located on navigable bodies of water where such transportation is cheaper than the cost of tank car operation.

CHAPTER 13

TANKER OPERATIONS

SHIPS' CHARACTERISTICS

Tankers and fleet oilers are designed to carry and deliver liquid cargoes with safety and speed. The structural layout of tankers is varied—their type, size, and arrangement being dependent on the requirements they are built to meet. However, there are certain characteristics which most tankers and fleet oilers have in common. (The term "Tanker" in this chapter refers to both MSTS tankers and fleet oilers unless otherwise indicated.)

Appearance.—In general, the modern tanker is characterized by the "three-island" type of construction—poop, bridge, and forecastle—with the propulsion machinery located aft. The appearance of a typical tanker is shown in figure 13-1. Owing to the relatively low freeboard, the main deck is frequently awash when fully loaded.

Cargo Spaces.—Much of a tanker hull is devoted to the carrying and handling of liquid cargo. The cargo space is divided into tanks by longitudinal and transverse bulkheads. These tanks are separated from the fore and aft parts of the ship by cofferdams—empty compartments having liquid-tight bulkheads on both sides.

Pipeline and Valve System.—A pipeline and valve system controls the flow of liquid cargo during loading, while underway, and in discharging. When loading the cargo is pumped or gravitated from the shore to the ship. In discharging pumps aboard ship push the cargo ashore or to receiving ships. An efficient pumping system is essential to commercial tanker operation.

Heating Coils.—In order to pump cargoes of heavy oil satisfactorily, it is necessary to preheat the oil by means of heating coils in the tanks. Provision for connecting such coils is, therefore, another important tanker characteristic.

Vent Lines.—Agitation or heating of petroleum bulk cargoes results in the formation of gases. If these gases are unable to escape to the atmosphere, undue stresses may be set up within the tanks and a rupture in the shell plating might result. Therefore, tankers must have some means of venting these gases. Conversely, upon cooling, vapors or gases inside the tank condense, creating a vacuum which can be relieved by the intake of air to prevent the possible buckling of plates. Vent lines are connected to each hatch and each line is usually fitted with a vacuum relief valve. These vent lines in turn are connected to headers which are carried up the masts and are fitted with flame arresters at the top. The vacuum relief valves are normally set to lift at a pressure of 2 pounds per square inch on the pressure side and a pressure of 1 pound per square inch on the vacuum side.

Safety Specifications.—Because of the constant risks of explosion and fire inherent in tanker operation, all tankers must meet rigid safety requirements which provide for expansion trunks over oil compartments; isolation of cargo spaces from machinery spaces, machinery boilers, and galleys; ventilation of oil spaces, cofferdams, pump rooms, and other spaces; pumping arrangements; and electric lighting systems.

The U.S. Coast Guard promulgates regulations governing safety at sea for U. S. flag tank vessels engaged in commercial service and carrying flammable or combustible liquid cargo in bulk. These regulations cover such matters as inspection and certification; requirements for hulls, machinery, and equipment; and operation (including general safety rules and rules for cargo handling).

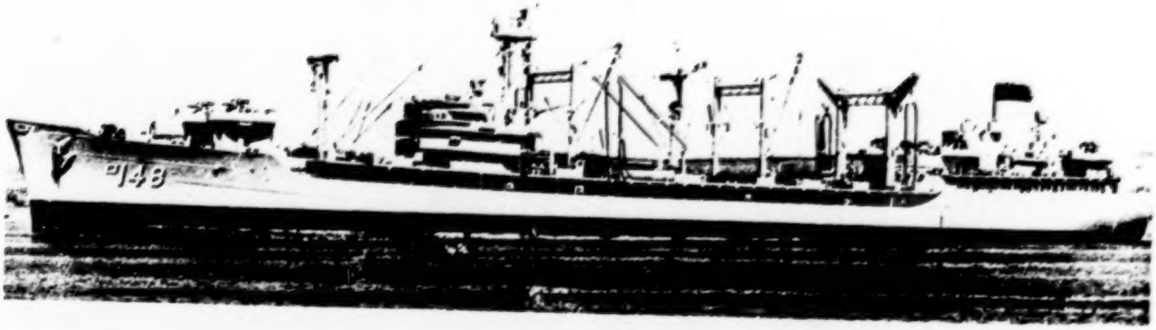


Figure 13-1.—Tankers are generally characterized by the "three-island" type of construction.

132.97

Fire-fighting Equipment.—The deck fire-fighting equipment includes the usual steamship equipment such as fire hoses, axes, buckets, and hand extinguishers. Most tankers are also equipped with a steam smothering system in the cargo tanks and pump rooms. A steam main leads from the ship's auxiliary steam line in the boiler room, with a master valve in the upper part of the boiler room. The smothering main line then leads forward along the deck with a branch for each fuel tank, cargo tank, and cofferdam, and to the forward holds, pump room, and other spaces if necessary. The sizes of the branch lines vary from 3/4 of an inch for the small spaces, to 2 inches for the large tanks. A CO_2 (carbon dioxide) fire extinguisher system may also be provided for protection of cargo tanks, fire room bilges, and electrical machinery.

Principal Types of Tankers

Types of tankers are broadly referred to according to their class. They are designated in a certain class depending on their deadweight tonnage (DWT). The DWT is the weight, in tons, of cargo and necessary fuel and stores which the vessel can carry at her load draft. Sometimes one design is used for a group of tankers, in which case the tankers in that group are referred to as being in the class of the first tanker of the group (e.g. USNS Maumee class, the SS Eagle Voyager class). Other classes are designed by the Maritime Administration and have a T in the designation (e.g. T2, T5, etc.).

Table 13-1 presents data on several types of tankers. Gradual improvements in hull design and in propulsion machinery have made possible the useful operation of tankers of increased size and speed.

Cargo Tanks, T2 Tanker

The compartment arrangement of tanks in a T2 tanker is shown in figure 13-2. Twin longitudinal bulkheads and 10 transverse bulkheads (exclusive of cofferdams) are provided, making 3 tanks abreast, with the exception of No. 1 tank which possesses a centerline bulkhead dividing the tanks into port and starboard compartments. This makes a total of 26 compartments.

Hatches for access to the tanks are usually circular in shape. Covers are the hinged-plate type, fitted with hemp and asbestos or neoprene gaskets to make them oil-tight. Ullage sounding holes which are holes approximately 8 inches in diameter, fitted with hinged covers are normally installed in the hatch cover, as shown in figure 13-3.

Table 13-1.—Types of Tankers

Design	Length Overall	Beam	Draft	Rated Speed	Cargo Capacity (bbls) (98% by volume)
T1-M-A2	311	49	15'6"	12.5	16,000
T1-M-BT2	325	48	19'2"	10	31,000
T2-SE-A1	524	68	30'2"	14.5	138,000
T5-S-12a	620	83	32'0"	18.5	186,000
20,000 DWT	572	75	30'3"	14.0	169,000
26,500 DWT	627	84	33'0"	19.0	200,000
29,000 DWT	645	85	33'2"	16.5	250,000
32,000 DWT	666	84	35'0"	18.0	259,000
35,000 DWT	676	93	34'9"	16.7	288,000
46,000 DWT	736	102	38'6"	16.5	367,000
67,000 DWT	860	104	43'6"	16.7	548,000
106,000 DWT	940	132	49'4"	18.3	892,000

The T2 tanker is designed to carry from a single petroleum product up to preferably not more than three different grades of petroleum products. The latter is made possible by the three-cargo-line system. (Some tankers have a piping system modified so that an additional number of products can be carried on a single vessel.) A T2 three-cargo-line system can be loaded with different grades of petroleum products because of the separate cargo lines and pumps for tanks No. 1 through 4; for tanks No. 5 and 6; and for tanks No. 7, 8, and 9.

Cargo Line System, T2 Tanker

The three-cargo pipeline and valve system of a T2 tanker is shown in figure 13-4. For purposes of simplicity, only the pipeline serving tanks No. 1 through 4 is discussed. It can be seen that this line runs along the deck and along the bottom of the ship, through all of the tanks. The pipe line on deck is connected to the pipeline at the bottom of the tanks by vertical lines fore and aft.

Bulk petroleum may be loaded through the pipe directly above tank No. 2, or it may be loaded above tank No. 5. In the latter case, the product goes through the pipeline along the deck, down the vertical pipe (aft), bypassing the pumps, to any or all of tanks No. 1 through 4. In discharging, the cargo from tanks No. 1 through 4 would be pumped through the pipeline along the bottom of the ship, through the pump room, and out—directly above tank No. 5.

Note that the pipeline for tanks No. 1 through 4 runs through the center tanks. Spurs projecting into the side tanks are fitted through the longitudinal bulkheads. Thus, a fluid under pressure in the main line can be introduced into each side tank.

Cargo Valves, T2 Tanker

The route of the cargo is controlled by valves operated manually on deck or in the pump room.

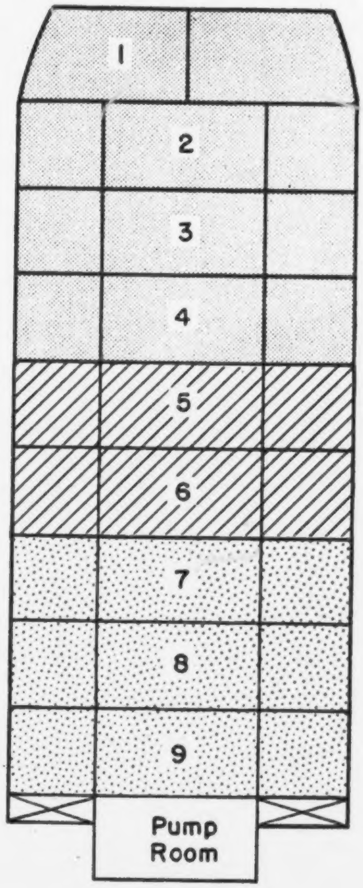


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Figure 13-2.—Three cargo arrangement of T2 tanker. There are separate cargo lines and pumps for tanks No. 1 through 4; for tanks No. 5 and 6; and for tanks No. 7, 8, and 9.

Because a turn of the wrong valve can result in contamination of an entire cargo, the handwheels on deck (which operate the valves in the cargo tanks) are painted various colors for identification. There are five types of valves, each operating on a different principle. These types are indicated in figure 13-4 and described briefly below:

1. Gate valves operate by means of a gate which slides across the opening through which the liquid passes.

2. Globe valves operate by means of a horizontally mounted disk which is pressed towards the circular seat opening to regulate the flow of liquid. When the disk comes against the seat opening, the shut-off is complete.

3. Check valves contain a free-moving mechanism designed to prevent backflow through the valve.

4. Relief valves open at a given pressure and seat when the pressure drops below the valve-setting pressure. They permit passage of the product through the valve. These valves usually operate by spring control.

5. Cross-over valves are designed with three openings instead of two and are placed at a junction of two pipelines to allow the liquid to flow through one, the other, or both of the lines, as desired. (Cross-over valves must be carefully watched to prevent commingling when cargoes of more than one grade are carried.)

Stripping System, T2 Tanker

The stripping system, not shown in figure 13-4, enters each compartment. As in the cargo system, the lines are located near the bottom of the tank. This system is designed for stripping the tanks dry of ballast or cargo but can be used for loading if check valves are removed.

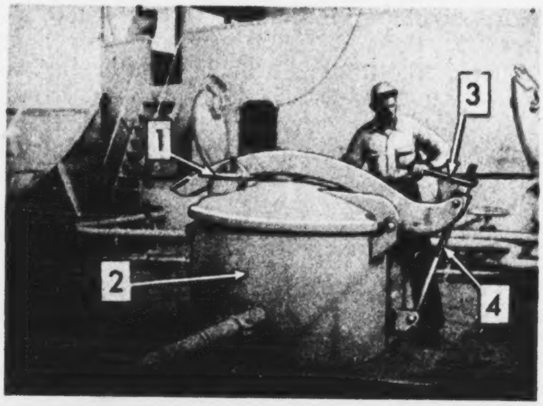

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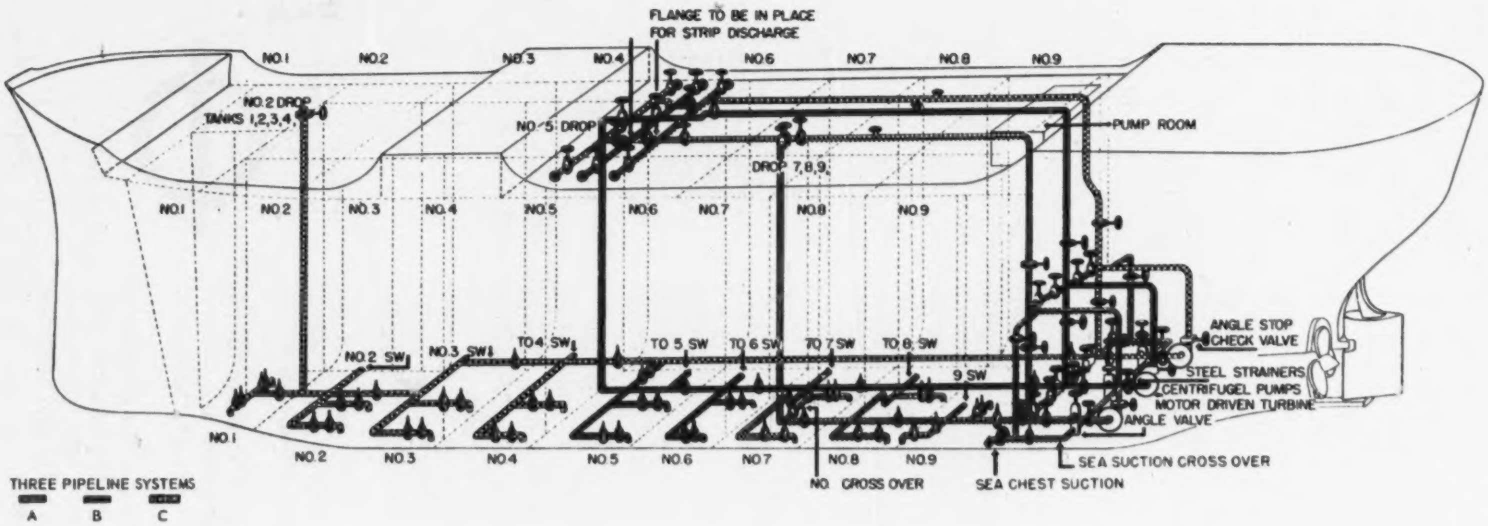
Figure 13-3.—Deck of T2 tanker showing tank hatch cover and ullage sounding holes: (1) ullage plug, (2) tank top, (3) tank top ratchet wrench, and (4) tank top lifting screw.


FLANGE TO BE IN PLACE
FOR STRIP DISCHARGE
NO.1
NO.2
NO.3
NO.4
NO.6
NO.7
NO.8
NO.9
NO.2 DROP
TANKS 1,2,3,4
NO. 5 DROP
PUMP ROOM
DROP 7,8,9.
NO.1
NO.2
NO.3
NO.4
NO.5
NO.6
NO.7
NO.8
NO.9
NO.2 SW
NO.3 SW
TO 4 SW
TO 5 SW
TO 6 SW
TO 7 SW
TO 8 SW
9 SW
ANGLE STOP
CHECK VALVE
STEEL STRAINERS
CENTRIFUGEL PUMPS
MOTOR DRIVEN TURBINE
ANGLE VALVE
NO.1
NO.2
NO.3
NO.4
NO.5
NO.6
NO.7
NO.8
NO.9
NO. CROSS OVER
SEA CHEST SUCTION
SEA SUCTION CROSS OVER
THREE PIPELINE SYSTEMS
A
B
C

132.100

Figure 13-4.—Pipeline and valve system of a T2 tanker.

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Cargo Pumps, T2 Tanker

Most T2 tankers have three main cargo pumps, one for each cargo system. These are centrifugal pumps which give thrust to the liquid they are pumping. Each main pump is capable of pumping 2,000 gallons per minute.

T2 tankers also have three-cargo stripping pumps. Two of these are motor-driven gear-type pumps. Each has a capacity of 400 gallons per minute. The third cargo stripping pump is steam-driven and has a capacity of 700 gallons per minute.

SHIPS' LOADING FACTORS

The master of a merchant vessel or the commanding officer of a fleet oiler prepares the loading plan for his vessel. Reference hereinafter will be made only to the "captain" of the ship—which is used to include both masters and commanding officers.) In preparing the loading plan, he must consider the loading factors discussed in the following paragraphs.

Tonnage and Capacity

The following terms are used with reference to a ship's loading capacity:

1. Gross Tons.—The entire internal cubic capacity of the ship expressed in units of 100 cubic feet to the ton, less certain exempted spaces (such as tanks for water ballast).

2. Net Tons.—The registered tonnage of a ship after certain deductions have been made from the gross tonnage, expressed in tons of 100 cubic feet. Among the deductions are crew spaces, navigation spaces, and the like.

3. Deadweight Tons.—The carrying capacity of a ship in tons of 2,240 pounds; the difference between light displacement and loaded displacement.

4. Light Displacement.—The weight of the ship excluding cargo, passengers, fuel, water, stores, and other items which are necessary for use on a voyage.

5. Loaded Displacement.—The weight of the ship including cargo, passengers, fuel, water, stores, and the like, which brings the vessel down to her load draft.

6. Cargo Deadweight Tons.—The number of tons (2,240 pounds per ton) which remains after deducting fuel, water, stores, and other such items necessary for use on a voyage, from the total deadweight of the vessel.

7. Barrel Capacity.—Cubic capacity expressed in barrels of 42 gallons (5.61 cubic feet). Barrel capacity is used to give a constant measurement since the weight of various liquids varies with the specific density of the liquid. For example, a ton of crude oil would occupy less space than a ton of gasoline.

Load Line

The load line is the line defining the maximum mean draft to which a vessel may be lawfully submerged. It is the lower limit of the freeboard for various conditions and seasons. (Freeboard is the distance measured vertically downward at the side of the vessel amidships from the upper edge of the deck line to the upper edge of the load line.)

Load lines, established by proper authority, must be permanently and conspicuously marked on the vessel by the load line disk, shown in figure 13-5. The disk is marked amidships below the deck line. The lines which indicate the maximum load line in different circumstances and in different seasons are horizontal lines. The abbreviations used are as follows:

S—Summer load line
W—Winter load line
WNA—Winter, North Atlantic load line
T—Tropical load line
F—Fresh-water load line
TF—Tropical fresh-water load line

The authority by whom the load lines are assigned may be indicated by letters marked alongside the disk and above the centerline; for instance, A—B for American Bureau of Shipping.

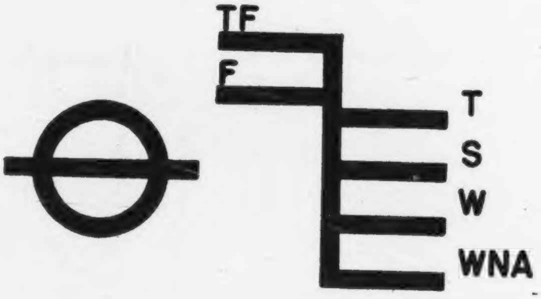

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Figure 13-5.—Load line markings.

International Load Line Certificates, issued by the Coast Guard, certify to the correctness of the load line mark.

Draft

The draft marks painted on either side of the bow and stern of a tanker indicate the depth to which the bow and stern are immersed. The draft marks, in conjunction with an immersion scale, indicate how many tons of cargo are required to immerse the ship 1 inch at any draft according to the deadweight scale on the ship's plan.

Trim

Trim is the longitudinal deviation of a vessel from her designated waterline at a given draft. The captain of a ship trims a vessel by arranging the weights in such a manner as to obtain desired immersion at the bow and stern. Trim tables or calculators may be used to compute quickly the effects on draft and trim caused by any selected distribution of weights throughout a loaded tanker.

Sag and Hog

Sag is that form of longitudinal deformation under stress in which the middle part of a ship's structure sinks below the extremities. Conversely, hog is the condition wherein the bow and stern are lower than the midship section. These conditions are illustrated in figure 13-6.

A tank vessel normally loaded will have a tendency to sag. This sagging is a result of the weight of the cargo in the tank section of the vessel. It will be most noticeable near the longitudinal center of the ship and may result in excessive stresses if the weight is concentrated in the longitudinal center of the cargo tank section. Sag also reduces the freeboard. If the freeboard is reduced by sag, the amount of cargo that can be carried—in compliance with load line requirements—is reduced.

Sagging can, at least in part, be eliminated if the weight is distributed in the end tanks with a corresponding reduction of the weight in the center tanks. Care in selecting the initial tanks to load—so that there will not be a concentration of weight in any section of the vessel—may also reduce sag.

A tank vessel in a light condition has a tendency to hog. This condition is the result of the weight of the stern section of the ship and of the normal weight of the forward end of the vessel. Under this condition, the center section of the ship largely carries the resulting stresses. These stresses, which are usually excessive, can be avoided by a judicious equalization of the weight in the ship. Such equalization is attained by proper loading, and ballasting.

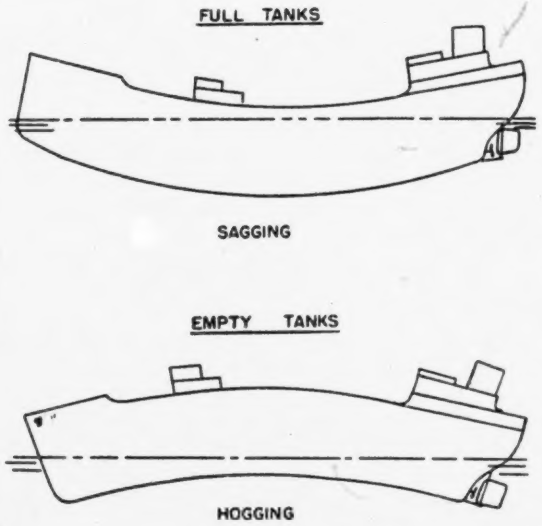

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Figure 13-6.—Sag and hog.

Tables for estimating the longitudinal stress induced in vessels in loaded and ballast conditions have been developed and are widely used throughout the tanker industry.

Ballast Layout

The amount and distribution of ballast contributes to a tanker's seaworthiness, maneuverability, and trim. Ballast also controls vibration by counteracting the stresses set up in the hull by unequal distribution of weight. In planning ballast layout, ballast tanks are selected to effect even distribution of weight throughout the hull, but must conform to the tank cleaning and inspection schedule.

Maximum Tonnage to Be Loaded

As previously stated, Load-line Regulations establish the line above which vessels cannot be loaded. Loading above this mark constitutes a safety hazard. Therefore, maximum tonnage to be loaded must be calculated accurately. The steps in this procedure are as follows:

1. The draft to which a vessel can be safely loaded (summer draft, tropical, fresh water, etc.) is ascertained.
2. In case of loading in a river, the water of which may be of a variable specific gravity, the gravity is obtained by means of a hydrometer and the ship's allowance is checked according to tables provided for this purpose.
3. Cargo deadweight tonnage is determined by deducting the sum total of bunkers, water, and stores from the ship's deadweight tonnage. This quantity, expressed in long tons (2,240 pounds), is the allowable weight to be carried. However, it does not necessarily mean that the volume of the oil which the ship can carry agrees with the weight the ship is legally allowed to carry.
4. The space the cargo will occupy, in proportion to the weight allowed, is then calculated. This is done by referring to tables provided, using the gravity of oil to be carried and the number of barrels per long ton. Available cargo space must then be checked to make sure that the ship can accommodate the scheduled cargo.
5. Sufficient space is then allowed—in proportion to the possible space required for the cargo—for cargo expansion, in the event that the tanker may enter regions where the temperature may exceed that of the oil loaded at the loading port. Tables are provided for use in determining the cargo expansion allowance.

CARGO HANDLING

Cargo Layout

In planning the cargo layout, the captain considers the loading factors discussed in the foregoing sections, and plans the cargo layout so that product contamination does not occur as a result of commingling. If the tanker is to load a full cargo of single grade product, the problem is relatively simple; but, if the tanker is to load more than one product, the problem is complex.

The captain bases his plan on his knowledge of the properties of the several products to be loaded, keeping in mind the tanker's structural plan—tank arrangement, bulkhead separation, type of valves, and cargo lines. In the case of split cargoes, the captain's loading plan is reviewed by a petroleum inspector who is the Department of Defense technical representative in port matters pertaining to petroleum products. As previously mentioned, basically, a T2 tanker is designed to carry three different grades of petroleum products. If more than three products are carried in a T2 tanker, there is a possibility of commingling which may or may not be harmful, depending on the grade of products handled.

The proper loading of a T2 tanker with three grades of products has been shown in figure 13-2. In this loading plan, the tanks for each grade of product conform to the cargo pipeline arrangement. Therefore, double valve separation exists in the lines between the different grades of products. If this plan is not followed, the three cargoes will be separated only by single valve separation between tanks. As a result, commingling from leakage is possible.

When only two grades of petroleum products are loaded on a T2 tanker, three loading arrangements are possible. These are shown in figure 13-7.

In the first arrangement, the bulkhead between tanks No. 6 and 7 separates the two grades. In the second, the bulkhead between tanks No. 4 and 5 separates the two grades. In the third arrangement, the bulkhead between tanks No. 6 and 7 separate the two grades of cargo.

When split cargoes are scheduled, it is preferable to load and discharge the split combination at a single docking or terminal. In this way, trim does not become a serious consideration. If two grades of cargoes can be loaded at a single docking and discharged under similar conditions, either of the first two arrangements, shown in figure 13-7, is preferable. However, if loading and discharging cannot be accomplished at a single docking, and either of the first two loading plans is employed, ballasting becomes necessary for proper trim. Therefore, when loading and discharging at a single docking is not possible, the third plan is preferable. It can be seen if tanks No. 5 and 6 are loaded first, the tanker will have sufficient trim to move from one terminal to another without the need of ballast. The third plan, however, has a distinct disadvantage in that there are two possibilities of bulkhead leaks—between tanks No. 4 and 5, and between tanks No. 6 and 7.

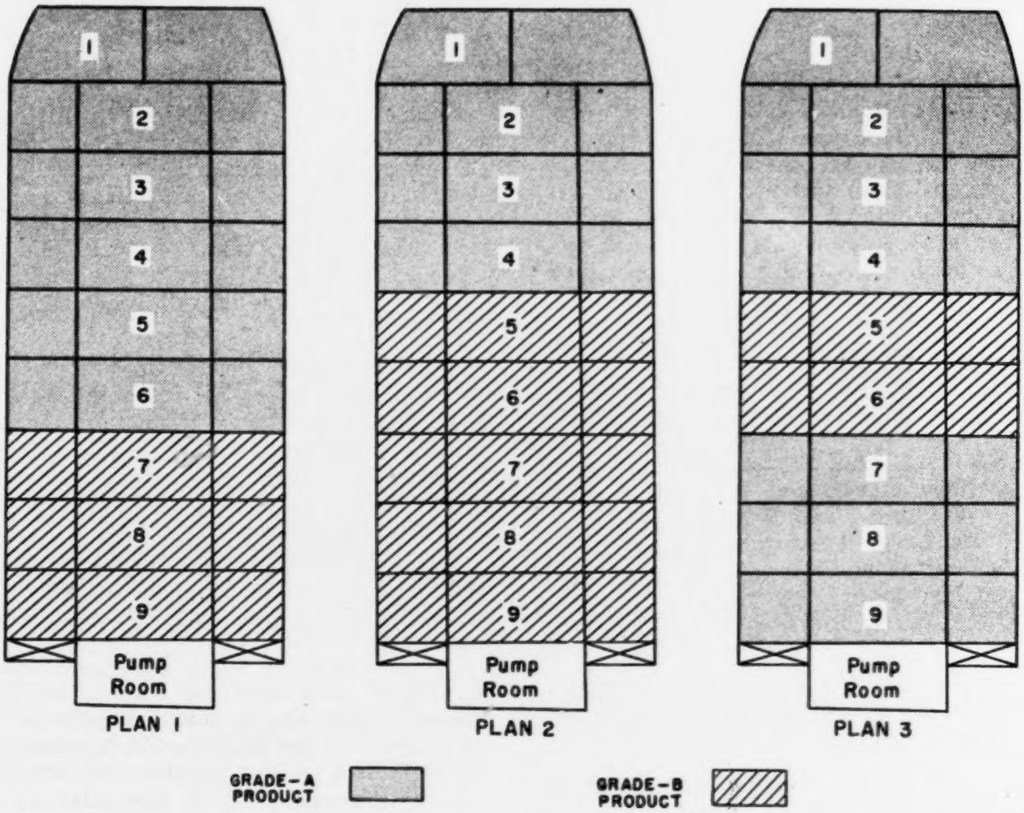

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Figure 13-7.—Three possible arrangements for loading split cargoes when only two grades of petroleum products are involved.

Cargo Heating

Certain cargoes, particularly heavy fuel oils, and some lubricating oils, require heating for the oil to flow freely in pumping and stripping. Current instructions require that MSTS tankers equipped with heating coils normally arrive at most discharge ports with Navy Special Fuel Oil cargoes heated to 100° F, or as close thereto as practicable. MSTS tankers carrying Navy Fuel Oil Grade Heavy cargoes are required to arrive at all discharge ports with the oil heated above 100° F, but not in excess of 120° F. Lubricating oils of medium viscosity require heating to approximately 100° F, and more viscous grades up to 120° F for good pumpability.

When heating of any cargo is required, care must be taken to ensure that the prescribed temperatures are at no time exceeded. Lubricating oils in particular deteriorate through the application of excessive heat. Also, excessively high temperatures increase the possibility of vapor lock in pumps which, in turn, may delay the operation of unloading.

On short voyages of 5 days or less, the most economical procedure is to keep the cargo heated throughout the voyage. On longer passages, the cargo may be allowed to cool. Heating must then be started far enough in advance so that the cargo will be at the desired temperature for discharging.

Cargo Transfer Procedures at Terminal

A summary of the major transfer procedures is presented in this section in order to give the overall picture of these operations.

Procedures Before Starting To Load or Discharge.—The captain consults with the terminal cargo superintendent to plan details of the operations. Before loading, the petroleum inspector inspects the ship's tanks and—in case of split cargoes—the ship's loading plan. When discharging, the inspector samples the cargo to ensure that it meets specifications.

The captain determines which valves, pumps, and lines are to be used. All valves are checked. Sea valves are closed and sealed. The cofferdams and pump room bilges are inspected for possible leakage of cargo lines into these compartments. Pump room bilge suction valves are checked and sealed in a closed position throughout a discharge operation. Deck scuppers are plugged and cemented to prevent drainage of any oil spill into the water. Warning signs are displayed and other safety regulations are followed. Hose connections are made between the ship and shore. The terminal attendant is given a "stand-by" order by the ship's loading officer before transfer operations are started or stopped, and before any change is made in transfer rate once transfer operations have started.

When the vessel and the terminal indicate they are ready to begin transfer, loading or discharging may begin.

Procedures When Starting To Transfer.—The vessel's manifolds are opened under the direction of the officer in charge of loading. Transfer of cargo proceeds slowly until an inspection reveals that everything is in good order. Then the rate of transfer may be increased to the maximum safe speed previously agreed upon by the captain and the terminal representative.

Loading Procedures.—The officer in charge of loading, knowing the approximate rate per hour at which the terminal expects to deliver cargo, checks at intervals the actual rate at which cargo is coming aboard.

Usually tanks are filled to a level somewhat lower than the final ullage, and then at a reduced rate to top off each tank in turn. Great care is exercised in topping off because of the possibility of oil spills.

Upon completion of loading, ullages and temperatures of all cargo tanks are taken. These are recorded in the ship's records.

Discharging Procedures.—The vessel's pumps are started, appropriate valves opened under the direction of the ship's cargo officer, and discharging commences. Stripping of some tanks may be started while the main cargo pumps are still discharging cargo from other tanks.

Before stripping is finished, the main cargo lines on deck and in tanks are drained to prevent oil from remaining in the vessel's lines. Hoses are drained before connections are broken whenever possible. After the vessel has completed discharging, tanks and cofferdams are inspected by ship's officers and by a petroleum inspector. Hoses are then disconnected.

Precautions in Transfer Operations.—During transfer operations, very rigid safety regulations must be followed: In addition, precautions must be taken against commingling and product contamination, against cargo shortages, and against harbor pollution. These precautions are discussed in subsequent sections.

The classification of petroleum products as flammable or combustible, and the safe handling of these products have been discussed in chapter 10. Commissioned vessels are governed, for safety purposes, by regulations promulgated by the Chief of Naval Operations, the bureaus concerned, and operational commanders. Safety regulations for MSTS tankers are prescribed by the Coast Guard and amplified by MSTS. All tanker personnel must be familiar with safety precautions applicable to their ships.

Coast Guard Classification of Products

For the purpose of regulating tank vessels, the Commandant, U. S. Coast Guard, divides flammable and combustible liquids into the five following grades:

Grade A: Any flammable liquid having a Reid vapor pressure of 14 pounds or more;

Grade B: Any flammable liquid having a Reid vapor pressure under 14 pounds and over 8 1/2 pounds;

Grade C: Any flammable liquid having a Reid vapor pressure of 8 1/2 pounds or less and a flash point of 80° F or below;

Grade D: Any combustible liquid having a flash point below 150° F and above 80° F;

Grade E: Any combustible liquid having a flash point of 150° F or above.

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Based on the above classification, petroleum products may be roughly grouped as follows:

- Grade A: Casinghead (natural) gasoline and very light naphtha;
- Grade B: Most commercial gasolines;
- Grade C: Most crude oils and some cut back asphalts (asphalt thinned with a volatile oil to make it fluid so that it can be used as a paint), creosote, benzol, toluol, alcohol; aviation gasoline Grade 115/145, JP-4 jet fuel.
- Grade D: Kerosine, JP-5 jet fuel, light fuel oils, and a few very heavy crude oils;
- Grade E: Heavy fuel oils, diesel fuel, road oil, lubricating oil, asphalt, and coal tar.

General Safety Precautions

1. Matches.—Use of other than safety matches is forbidden on tank vessels at all times.

2. Smoking.—Smoking is prohibited on the weather decks of any tank vessel when loading or discharging cargo, when gas-freeing tanks, or when lying at the docks of an oil terminal. The senior officer on each tank vessel should make his own rules for the guidance of the crew as to when and where smoking is permissible.

3. Cargo Tank Hatches and Ullage Sounding Holes.—No tank hatch, ullage hold, or tank washing plate shall remain open without flame screens, except under the supervision of the senior members of the crew on duty, unless the tank opened is gas free.

4. Fresh-Air Breathing Apparatus.—On tank vessels where the distance from the deck to the bottom of the cargo tanks exceeds 15 feet, fresh-air breathing apparatus, including belt and lifeline, is required. This apparatus, rather than an all-purpose gas mask, should be used when entering compartments. Cargo tanks which are not known to be gas-free should not be entered by anyone not provided with and experienced in the use of this apparatus.

5. Ventilation.—Engine rooms, living quarters, and other spaces where members of the crew normally may be employed, must be ventilated for protection of personnel. Where mechanical means for ventilation are provided for pump engines, or other engine rooms, they must be turned on a sufficient length of time before starting engines to ensure the removal of possible flammable vapors.

Safety Regulations for Transfer Operations

Following are some of the Coast Guard regulations which apply specifically to loading and discharging operations:

1. Handling of General Cargo or Stores.—Packaged goods, freight, and ship's stores shall not be loaded or discharged during the loading of flammable oils (grades A, B, C) without the permission of the senior deck officer.

2. Warning Signs.—During loading and discharging, a warning sign is displayed conspicuously at the gangway. This sign reads:

DANGER
No Open Lights
No Smoking
No Visitors

3. Cargo Transfer Signals.—A red flag shall be displayed by day during transfer of petroleum cargo at anchorage or dock. At night, an all-round red light shall be displayed when transferring petroleum at a dock.

4. Vessels Coming Alongside.—No vessel shall come alongside or remain alongside a tank vessel in way of its cargo tanks while it is loading Grades A, B, or C products without having permission of the officer-in-charge of the vessel which is loading.

5. Galley Fires.—Galley fires are normally permitted during cargo transfer: Provided that prior to loading Grades A, B, and C cargoes, the senior deck officer shall make an inspection to determine whether in his judgment galley fires may be maintained with reasonable safety during the loading operation.

6. Boiler Fires.—Boiler fires are normally permitted during cargo transfer operations: Provided that prior to loading Grades A, B, and C cargoes, the senior deck officer shall make an inspection to determine whether in his judgment boiler fires can be maintained with reasonable safety during the loading operation.

7. Over-All Loading.—Over-all loading (through open hatches) of Grades A, B, and C cargoes is prohibited. This restriction also applies to Grades D and E, with the exception of lube oils which may be loaded over-all when the cargo system does not lend iteself to the use of pipe connections. Over-all loading is, however, an added danger and every protection must be taken.

8. Spills.—If a cargo spill takes place during loading or discharging, transfer operations must be stopped. All necessary precautions must be taken to eliminate possible sources of vapor ignition.

Precautions Against Contamination

Major importance must be attached to training and instructing personnel aboard ship to safeguard against contamination.

Product contamination can occur as the result of an improper loading plan. Careful planning of cargo layout is a necessary precaution against commingling. Other precautions prior to loading include careful checking of tanks, lines, and pumps to ensure that they are suitably clean for receiving cargo; the testing of tank bulkheads, main and stripping lines, and valves for leaks; and the lining up of cargo valves with the greatest of care.

Ballast is another source of product contamination. To prevent such contamination, the simultaneous transfer of cargo and ballast is prohibited except in an emergency. Cargo loading must not be started until the pumping of ballast is stopped and valves secured; conversely, ballasting should not be started until the pumping of cargo is stopped and valves secured.

The venting system and the steam smothering system are also sources of contamination. The possibility of contamination through the venting system must be prevented by ensuring that pressure-vacuum valves are in operating condition. Similarly, the possibility of contamination through the steam smothering system must be prevented by ensuring that check valves are in operating condition.

Cargo hose connections to shore must be checked prior to transfer operations to prevent the transfer of cargo into the wrong cargo lines.

To prevent water from seeping into tanks, tank tops and ullage, plate gaskets must be kept tight.

Tank interiors should be coated for carrying clean products and must be coated for carrying JP-5 Jet Fuel. Several acceptable coatings have been approved by the Department of Defense. The primary purpose of tank coatings is to prevent tank corrosion and rust contamination of product.

Precautions Against Cargo Shortages

Careful ullage measurements are taken after loading is finished, prior to discharging, and before and after every transfer of cargo. Cargo losses through carelessness must be prevented. Cargo may be lost through overboard discharges or sea suctions, spills, overflow at sea, leaks, and by displacement by water. Such losses can be minimized by attention to the following precautions:

1. Indications of leakage overboard should be watched for, and sea suction valves rigidly inspected.
2. Cargo pump scaling glands must be carefully adjusted and inspected to prevent losses into bilges and cofferdams.
3. Sufficient allowance for expansion must be made when loading, to prevent tank overflow at sea.
4. Hull and rivet leaks should be detected promptly and repaired immediately.
5. Tanks tops and ullage holes must be securely dogged down to prevent the entry of water which can cause loss of cargo by displacement.
6. Tanks and lines should be drained completely after transfer operations.

Precautions Against Harbor Pollution

The Oil Pollution Act of 1924 prohibits the discharge or escape of oil or water containing oil from any vessel into navigable coastal waters of the United States. Heavy penalties are imposed for violation of this act. Similar laws are enforced by most countries throughout the world, with corresponding heavy penalties. Harbor pollution may occur as a result of improper ballasting operations or by spills and leaks while transferring cargo.

The following harbor regulations, common in ports throughout the world, are concerned with ballasting operations:

Oil and Ballast Disposal.—No oil or water containing oil shall be dumped overboard within 100 miles of land, except in case of an emergency imperiling life or property. Vessels finding it necessary to drain tanks of dirty ballast, or discharge slop, when within the 100-mile zone, may discharge the water beneath dirty ballast or slop as practicable. A careful watch should be maintained to ensure that no oil goes overboard. The remaining ballast containing the slop from each of the tanks, shall be pumped into one tank, the contents of which shall be pumped ashore or into barges on arrival in port.

Pumping Ballast in Port.—Only clean ballast water shall be pumped overboard in port, dirty ballast being disposed of by pumping directly ashore or into slop barges.

When pumping clean ballast overboard in port or within the 100-mile zone, it is advisable to discharge it over the top rather than through the sea suction. This procedure provides an opportunity for continuous checking to ensure that no oil is being pumped overboard. In such cases, it is advisable to have a man standing watch by the discharge hose.

During transfer of cargo, ship's officers must guard against spills, burst hoses, and leaks through sea suction valves and overboard discharges. If an oil spill occurs within a harbor, the captain must get in touch with the terminal representative immediately and try to confine the oil and prevent its spread.

TANK CLEANING AND GAS-FREEING

The twofold purpose of tank cleaning and gas-freeing is (1) to ensure that tanks are in condition to receive cargo without contamination of products; and (2) to lessen the hazard, to men and to vessel, created by the accumulation of gas vapors.

Approved tank cleaning and gas-freeing procedures have been established by the Navy and are promulgated jointly by the Bureau of Ships and the Military Sea Transportation Service in the Cargo Tank Cleaning Manual, NavShips 250-341; MSTS P 105, September 1950. Only a general discussion of the subject is included in this chapter.

Types of Tank Cleaning (General)

Tank cleaning can be conveniently classified under four categories, according to the degree of cleaning necessary to meet operational or material requirements. The categories are: (1) periodic maintenance cleaning; (2) cleaning and gas-freeing for tank inspection and/or repairs; (3) cleaning and gas-freeing for shipyard overhaul; and (4) cleaning for change of cargo.

Periodic Maintenance Cleaning

To maintain the tanks of a vessel properly, it is necessary to clean the cargo tanks periodically, removing from within the tanks accumulations of scale, sediment, and leftover residue from previous cargoes. An illustration of a scale condition in a cargo tank on a black tanker is shown in figure 13-8. If this scale is allowed to remain, it will clog limber holes and strainers, thereby retarding the cargo discharge and stripper rates.

In the case of clean vessels, especially gasoline carriers, scale usually accumulates in the upper parts of a tank. Periodic removal of this scale helps to retard future scale formation and also makes future gas-freeing easier. In addition to lessening cargo contamination, cleanliness of tanks and the absence of bottom accumulations aid in maintaining good cargo stripping, thereby helping to prevent attendant cargo losses. On black-oil vessels, the heaviest accumulations are on the bottom.

Although tank cleaning is beneficial in many ways, it is necessary to consider in some cases, as in black vessels, that the oil film on the tank interiors also serves as a protective coating which slows down corrosion. Washing tank sides and internal members, therefore, should be avoided unless an actual need exists.

Gas-Freeing for Tank Inspection or Minor Repairs

Occasionally tanks must be gas-freed in order to inspect bulkheads for leaks or to make minor repairs to valves, extension rods, pipelines, and the like. The term "gas-free" means free from dangerous concentration of flammable or toxic gases.

For inspection or minor repairs, however, it is not usually necessary to gas-free the entire vessel, but only the tank or tanks to be entered and adjacent spaces. These areas need be rendered gas-free only for the period of time required for the inspection or repairs.

A cleaning operation assists greatly in gas-freeing by removing oil as well as knocking down loose scale accumulations which may regenerate vapors. To obtain a gas-free condition, it is necessary to ventilate the tanks by renewing the air in them several times. This may be carried out either by natural means or by the use of such mechanical devices as gas exhausters, ventilating fans, or blowers. Ventilation is continued at all times when men are in the tanks.

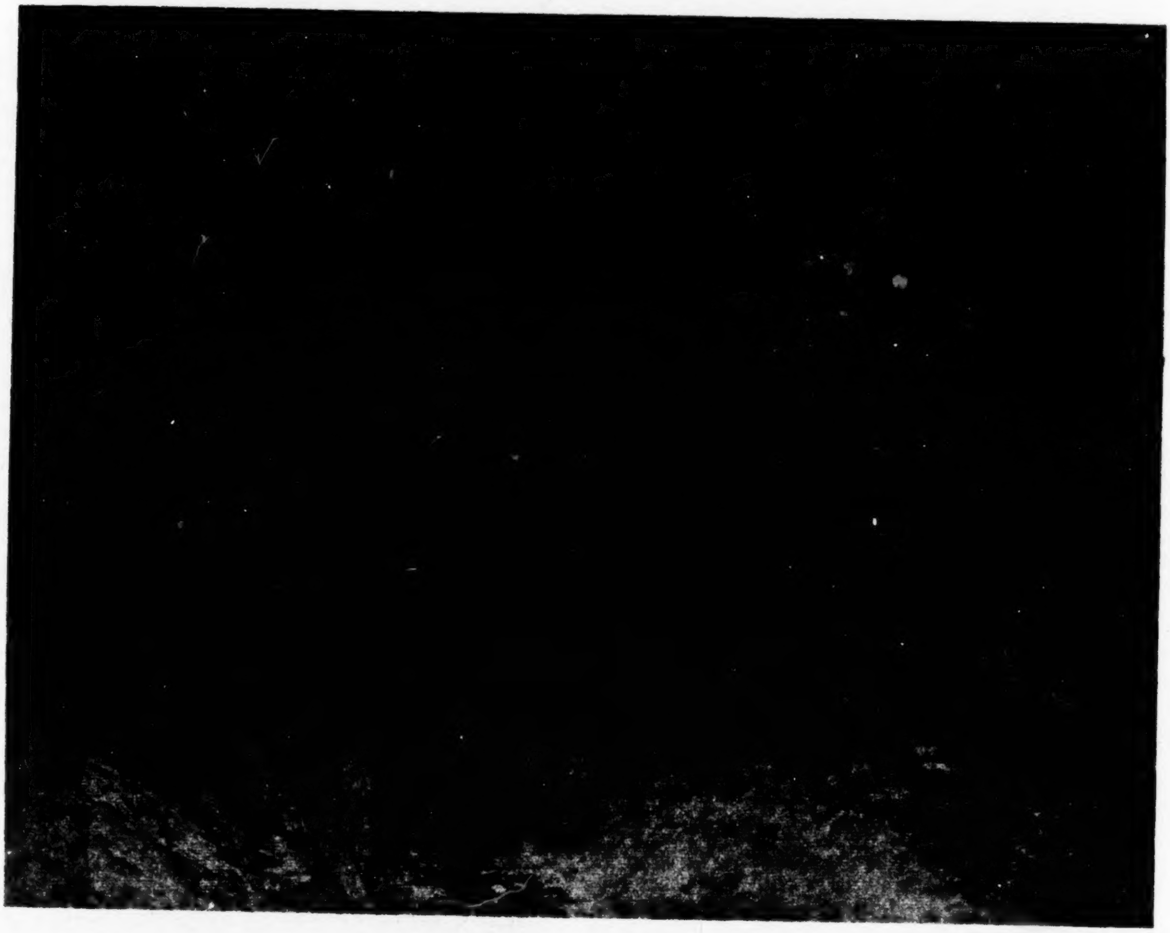

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Figure 13-8.—Scale condition in a cargo tank.

Gas-Freeing for Shipyard Overhaul or Major Repairs

A vessel entering a shipyard for overhaul is subject to much stricter regulations in regard to the cleanliness and gas-free condition since work to be done in the tanks usually requires the use of sparking tools and hot work. The vessel must be maintained in a gas-free condition for the entire overhaul period; all sources of oil and vapors must be eliminated to ensure against regeneration. A thorough gas-freeing of this type involves complete removal of all traces of oil and vapors in all the spaces, including that behind or soaked into rust and scale. Pockets of oil and/or vapor behind scale and in dead-ends of pipelines are potential sources of gas regeneration.

To help achieve the required cleanliness and gas-free condition, a thorough routine cleaning is recommended, followed by extensive tank ventilation, mucking, and hand hosing of the bottoms.

A thorough machine cleaning usually knocks down and breaks up considerable scale, permitting oil thus freed to be pumped away and, at the same time, providing easier mucking. This greatly reduces the likelihood of gases being regenerated during periods of shipyard availability.

Cleaning for Change of Cargo

Cleaning for change of cargo includes cleaning: (1) for change to a similar product (as from JP-5 to diesel); (2) for change from gasoline to clean product such as diesel fuel or JP-5; and (3) for tanker conversion from black to clean service.

When a change of cargo is made to a similar product, the operation involves the removal of all the previous products and removal of sediment from the cargo tanks, pipelines, and pumps.

When a change of cargo is made from gasoline to a distillate fuel such as JP-5 or diesel fuel, the heating coils and steam smothering lines should be blown out with steam or hot water. Cargo tank vent lines should be flushed out with hot water and the entire vent line system allowed to drain. Cargo tanks should be washed with a mechanical type washing machine. Tank tops should be opened and windsails or mechanical blowers used if necessary to gas free the tanks to allow personnel to enter each tank to hand hose tank bottoms and remove loose scale and sediment. Cargo pipelines and cargo pumps should be cleaned by pumping clean water through each pump and pipeline. All pipelines should be drained upon completion of flushing.

When a tanker is being converted from black to clean service, a more complex cleaning operation is required. In converting from black oil to diesel fuel, tanks must be clean and free of oil residues, wax, and sediment, as these materials tend to promote discoloration, corrosion, and gum in diesel cargoes. However, the highest degree of tank cleanliness must be accomplished for conversion from black oil to gasoline, kerosine and jet fuel service. Tanks scheduled for carrying these products must be exceedingly clean. Unless the needs are imperative for changing from black directly to gasoline, kerosine or jet fuel service, it is strongly recommended to first carry a cargo of diesel. Fuel oil, oil residues, wax, sediment, loose scale, or water in tankers scheduled for conversion should not be permitted as these contaminating factors cause unsatisfactory thermal stability, increased corrosion, gum formation, and depreciation of the quality criteria in general.

Routine Machine Washing of Tanks

Routine machine washing is a basic operation consisting of washing the tanks with streams of hot or cold water under pressure. A tank washing machine, shown in figure 13-9, is a mechanically rotated nozzle device which is attached to the end of a hose and inserted into the tank through a deck opening located in the top of the tank. The machines are placed at various levels within each tank.

The cycle of routine tank washing, from the sea suction to the machine in the tanks, is shown in figure 13-10. Sea water is brought in through the sea suction, goes through the fire and tank washing pumps (where the pressure is boosted), thence to the heater, through the fire line, and then to the machine in the tank.

Steam Cleaning

Steam cleaning of tanks is resorted to only when washing machines are not available. Three disadvantages of this method of tank cleaning are as follows:

1. The safety of the vessel is endangered as steaming causes thermal strains on the hull with attendant rivet leaks and acceleration of corrosion. Also, steaming causes a greater quantity of gases to be discharged on deck.

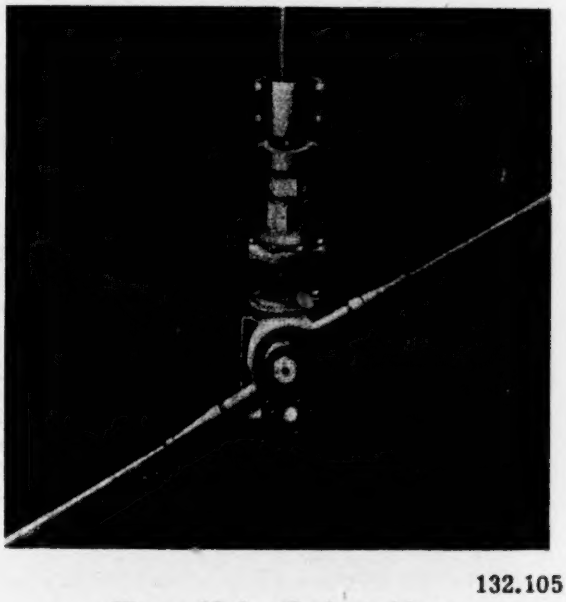

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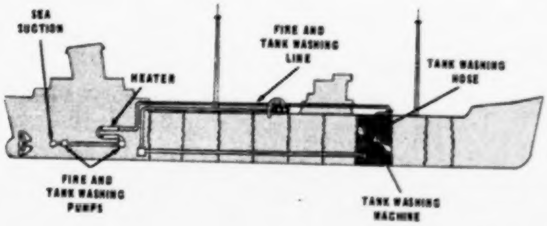
Figure 13-9.—Tank washing.



132.106
Figure 13-10.—Routine tank washing cycle.

2. Steam cleaning requires more time.
3. It is less economical because steaming tanks appreciably increases the burden on the boilers and the average speed of the vessel is probably reduced on steam vessels. Increased fuel consumption is a natural result, due to the extra time required for gas-freeing by this less efficient method.

Tank Ventilation

After a cargo tank has been cleaned by machine washing or other method, ventilation is necessary to obtain a safe gas-free condition. Ventilation is begun immediately after tank cleaning, while the tank is still hot and before cooling has condensed the heavier vapors back to a liquid. Ventilation may be accomplished by any one of the following means: windsails; gas exhausters; or ventilating fans and air blowers.

Windsails.—A windsail consists of a canvas chute that can be hoisted above the deck by means of a halyard, and a long canvas duct that extends down into the tank. Natural ventilation may then be accomplished by trimming the windsail into the wind. The efficiency of the windsail depends on the force and direction of the wind. In a moderate breeze it is fairly effective.

Circulation of air throughout the entire tank is set up by placing the lower end of the canvas duct near the bottom where the heavy vapors settle. The air caught by the chute is funneled down through the duct to the bottom where it forces the gases to the top of the tank, allowing them to escape to the deck through the open tank top.

Gas Exhausters.—After a tank has been allowed to cool, especially when there is a lack of natural ventilation, gas exhausters or ventilating fans are used to dispose of gas vapors quickly.

Gas exhausters are devices which serve to gas-free a tank by the continuous renewal of air in tank spaces. Belonging to the class of aspirators, they are not designed for high vacuum but for a large carrying capacity. The gas exhauster is particularly effective in the gas-freeing of gasoline tanks as it reduces the washing time when the machine system is used.

A gas exhauster is shown in figure 13-11. In this typical installation, a 10-inch exhauster is connected to a standard 10-inch expansion joint which acts as a swivel joint so that the discharge end of the exhauster may point either to port or starboard. The gases are then carried away by the prevailing wind.

Air Blowers.—Air blowers are used to move considerable air in a short time by a vacuum action which is regulated by the force of compressed air.

Mechanical Blowers or Ventilating Fans.—These are power-driven fans of the centrifugal type and are found to be efficient in many types of work. They are equipped with explosion-proof motors so they may be used for ventilating tanks and spaces containing explosive vapors.

132.107
Figure 13-11.—Gas exhauster installed aboard a modern tanker.

The advantages of the air blowers and ventilating fans are that they can be reversed so that air can be forced into the tank as well as sucked out, and they are built of nonsparking materials. Equipping these blowers or ventilating fans with long canvas socks or with noncollapsible hose tubes, permits placing the air or suction at any desired point in the tank, and the efficiency is increased. They may be made in practically any size, and are easily rigged and handled by any one on the job. They are excellent for removing heavy gases, such as carbon dioxide, from the bottoms of tanks.

INSPECTION

The petroleum inspector is responsible for quality and quantity of the product and determines the suitability of a tanker to load without adversely affecting the quality of the product. He has no authority relative to the actual operation of the ship, but the captain cooperates with the petroleum inspector in order to coordinate loading operations.

A summary of vessel inspection procedures is given herein in order to furnish an overview of the functions of the petroleum inspector in tanker operations.

Preliminary Inspection

Prior to loading the inspector checks the following: availability of cargo to be loaded; shore tanks; loading lines; ship's tanks; and the planned layout of split cargoes.

Availability of Cargo.—Upon receiving a nomination of a vessel scheduled to lift petroleum, the inspector checks with the supplier to determine that sufficient quantities of the product or products are available for loading at the proper time. He determines that the product will be ready to be loaded when the vessel arrives.

Shore Tanks.—He samples and tests all shore tanks to be used for the cargo to determine that the product meets the required specifications. He also gages the shore tanks.

Loading Lines.—He determines, by sampling, that all pipelines to be used are full and contain on-specification products from approved shore tanks and do not contain any water.

Ship's Tanks.—On docking of the vessel, the inspector, in company with inspection personnel representing the contractor, boards the vessel and develops information from ship's personnel regarding previous cargoes carried, tank cleaning performed since the last cargo, the present condition of the ship's tanks and lines, and the estimated length of time required to deballast completely. It is important that any recommendations regarding readying the ship for cargo be made as early as possible so that any cleaning or gas-freeing operations can be arranged with minimum delay in ship turnaround.

When the ship's tanks are ballast-free and suitably clean, the inspector makes a personal inspection of all tanks. Particular attention is paid to rust and scale, especially when aviation fuels and lube oil cargoes are to be loaded.

When loading aviation fuels, the inspector requires that samples of the rust be taken from the tanks and tested with the fuels to determine the effect upon its corrosiveness and tendency to form gum.

The tank bulkheads and bottoms are thoroughly examined after all tank stripping has been accomplished. The ship's main cargo lines are drained to one tank, preferably aft, which is then emptied by the stripping system. The stripping system is then cleaned of ballast water by blowing with compressed air or steam.

Inspection During Loading

After sufficient cargo is pumped into one tank, the inspector may request the ship's officer to switch from this tank to other tanks and continue loading. A sample drawn from the first tank will then give a very good indication of the product being received in the ship. After the sample has been drawn and found by test to be satisfactory, the first tank is then available for receiving more cargo.

Immediately upon commencing loading, a sample is drawn from the shore line near the hose connection. This sample is visually inspected for water and contamination and is forwarded to the laboratory for spot tests. During the loading, periodic samples are drawn from the loading lines for spot testing at intervals designated by the inspector. These samples may then be composited for analysis as a check on cargo sample results.

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Upon completion of loading, the shore tanks are closed off and gaged. Since water level in the tank bottom should not change appreciably during the loading, any decrease may indicate that water has probably been loaded on the vessel. In the event of any decrease of water level in the shore tanks, a sample is taken near the bottom of the ship's tanks to indicate the presence of water.

Samples are taken from the ship's tanks after loading is completed. Ship's tanks are also gaged and the temperature of the product in the tanks determined.

Inspection During Discharging

When discharging, the same procedures apply as in loading, with few exceptions. On arrival, samples are taken from the vessel's tanks, and tests are run to determine quality of product. The ship's tanks are gaged, and the temperature of products determined. The ullages are compared with those obtained when the loading of the vessel was completed. After corrections for temperature differences are made, the ullage readings are compared to determine whether any shifting or shortage of cargo has taken place while the vessel was in transit.

The shore tanks and loading lines are checked for suitability before a receipt of cargo. The shore tanks are then gaged. Temperatures are determined and samples taken before and after discharging. Shore lines are also checked after completion of discharge.

FUELING AT SEA

Mobile logistic support is an important element in operational logistics. During World War II, it was a significant factor in furnishing supplies and services to overseas fleet units in advanced areas. It continued to be so in Korean operations and will be employed in the support of overseas fleets in any future emergency. Mention has already been made of floating storage and its importance in supplying units in advance areas. A brief description of fueling at sea is included because it, too, is an important procedure in operational logistics. Furthermore, it is a unique method of petroleum distribution, developed by the Navy for support of the fleets.

The term fueling at sea is applied to the operation of transferring fuel from one vessel to another in an open sea while the vessels are under way (fig. 13-12). In general, fuel may be transferred between most auxiliary and combatant type vessels if the necessary equipment (hose, booms, tackle) is available. However, in practice, the transferring vessel in refueling operations is an auxiliary vessel called an oiler. The Service Forces have primary interest in this procedure. A complete description of these operations appears in the fleet publication, NWP 38 series, Replenishment at Sea.

Primary Considerations

Fueling at sea is a military operation which must be conducted so that logistic support is furnished with minimum interference with the primary operation in progress and with minimum risk of damage due to enemy action or other causes. Thus the operation must be performed in the least possible time consistent with reasonable safety, making use of courses and speeds which deviate the least from the requirements of the primary operation.

The most effective means of reducing overall time is by intelligent planning and preparation. Where several ships are to be replenished, the order in which they are assigned to come alongside should be one which would require minimum changes of rig by the auxiliary ship or of arrangement for issue of fuel. As soon as each ship is alongside and connected, transfer must commence and continue without interruption.

Risk of damage due to collision, weather, or failure of equipment, as well as its improper handling, is increased by attempts to cut time below that compatible with the state of training or by lack of constant watchfulness and care on the part of all connected with the operations.

The fueling at sea operation must be conducted in a manner that will permit immediate cessation of operations for defensive action. Increased risk of damage due to enemy action is present because ships must take a close position and suffer restricted maneuverability. Procedures, equipment, and training must be utilized which permit the ships involved to act offensively and defensively with maximum efficiency during the refueling operation and to break away expeditiously in an emergency. All gear and rigging must be tended constantly and the handling crew must be trained to disconnect and return all gear instantly when so ordered. Insofar as practicable, it is important that the

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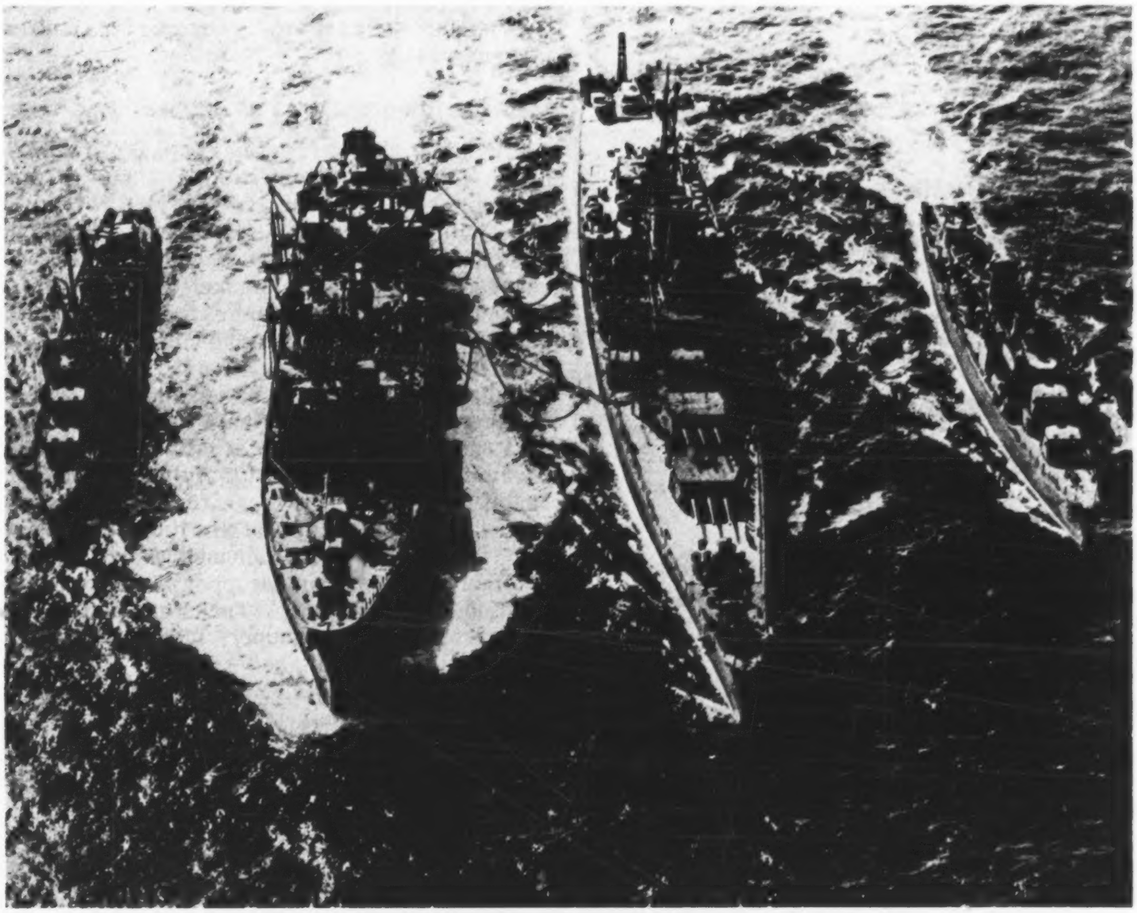

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Figure 13-12.—Fueling at sea.

burden of all possible rigging and handling thereof be assumed by the fleet oilers to enable combatant ships to take defensive action with the least possible delay.

Rates of Transfer

The quantity of oil that can be delivered from one vessel to another within a specified time, apart from weather and sea conditions, is governed by one or more of the following factors:

1. Number, size, and type of fuel hose used
2. Temperature and viscosity of oil
3. Pressure maintained at the transfer pump discharge
4. The suction conditions of the fuel-oil transfer pumps, including the size of tank tail pipes and number and location of tanks cut in
5. Arrangements of the vessel being fueled for the best distribution of oil received
6. Arrangements on the fueling vessel for providing the best possible rigging and handling facilities
7. Design pressure drop inherent in the piping of either vessel
8. Capacity of fuel-transfer pump
9. Method of fueling used

10. Design of the stowage tanks, overflow, and escape system of the receiving vessel.

Pumping Rates

Pumping rates to be expected approximate the following:

Fuel Oil
  3000 GPM with 7-inch hose
  2000 GPM with 6-inch hose
  1250 GPM with 4-inch hose—four hoses
Gasoline
  1000 GPM with 6-inch hose
  500 GPM with 4-inch hose
  100 GPM with 2 1/2-inch hose
Diesel Oil
  1000 GPM per 4-inch hose
JP-5
  3000 GPM with 7-inch hose

Rigs for Fueling at Sea

There are three accepted rigs for fueling at sea, namely, the Spanwire rig, the Close-in rig, and the Heavy Weather rig. The essential difference between these rigs lies in the method employed to extend the hose between the ships involved.

In the Spanwire rig, the hose is extended by the use of a wire rope rigged between the two ships on which trolley blocks, supporting the hose, are run. In the Close-in rig, the hose is extended by the use of saddles supported by boom whips and bight lines to booms or other high locations on one or both ships. The Heavy Weather rig is essentially the same as the Spanwire rig except that the rig is modified to accommodate 315 feet of 7-inch hose.

The use of a spanwire to support the hose permits the ships to open out to between 140 and 180 feet to transfer fuel comfortably. The Heavy Weather rig permits a maximum ship separation of 260 feet. When using the Close-in rig, the distance to which ships may open to fuel comfortably is limited to about 80 feet. The greater separation of ships engaged in fueling permitted with the Spanwire rig and Heavy Weather rig will frequently allow the choice of a fueling course which is closer to the desired direction of advance, and hence results in substantially less interference with the primary mission of the force being replenished. These methods also provide for greater speed through the water while fueling, greater tolerance in station keeping, greater maneuverability, and greater use of antiaircraft batteries in the event they are needed during fueling.

A sketch showing the Spanwire rig is shown in figure 13-13.

MSTS Limited Fueling at Sea Capability

Another method of fueling at sea is the broadside method, whereby MSTS tankers and privately-owned tankers are provided with limited equipment and gear for transfer of bulk petroleum products at sea. These tankers are engaged regularly in commercial type operations of worldwide point-to-point transportation of cargo. However, they have had minor alterations which include tripods on the main deck, quick closing valves, pipeline extensions, and limited equipment which enable them to receive fueling rigs and hoses from fleet oilers, carriers, or cruisers for transfer of their cargoes. This capability of fueling at sea from tankers provides a valuable contribution to the readiness of the fleet. It provides an underway capability available for contingency operations or in the event of an emergency. Transfers can be particularly useful in resupply of bulk petroleum products to fleet oilers. Thus, the oilers can remain on the service line instead of having to break off operations, steam to a loading port, load, and return to station.

MSTS OPERATIONS

The Military Sea Transportation Service is responsible for providing ocean transportation requirements for all military services and for other agencies or departments as directed. MSTS is under the military command of the Chief of Naval Operations. For procurement purposes and related matters, MSTS is responsible to the Assistant Secretary of the Navy (Installations and Logistics).

MSTS headquarters are located in Washington, D. C. Four major area commands are located at New York, San Francisco, London and Yokohama. Under the area commands are subarea commands and offices which are established at whatever worldwide locations the volume of MSTS business justifies.

Mission of MSTS

The mission of MSTS includes the operation of tankers and oilers of the MSTS

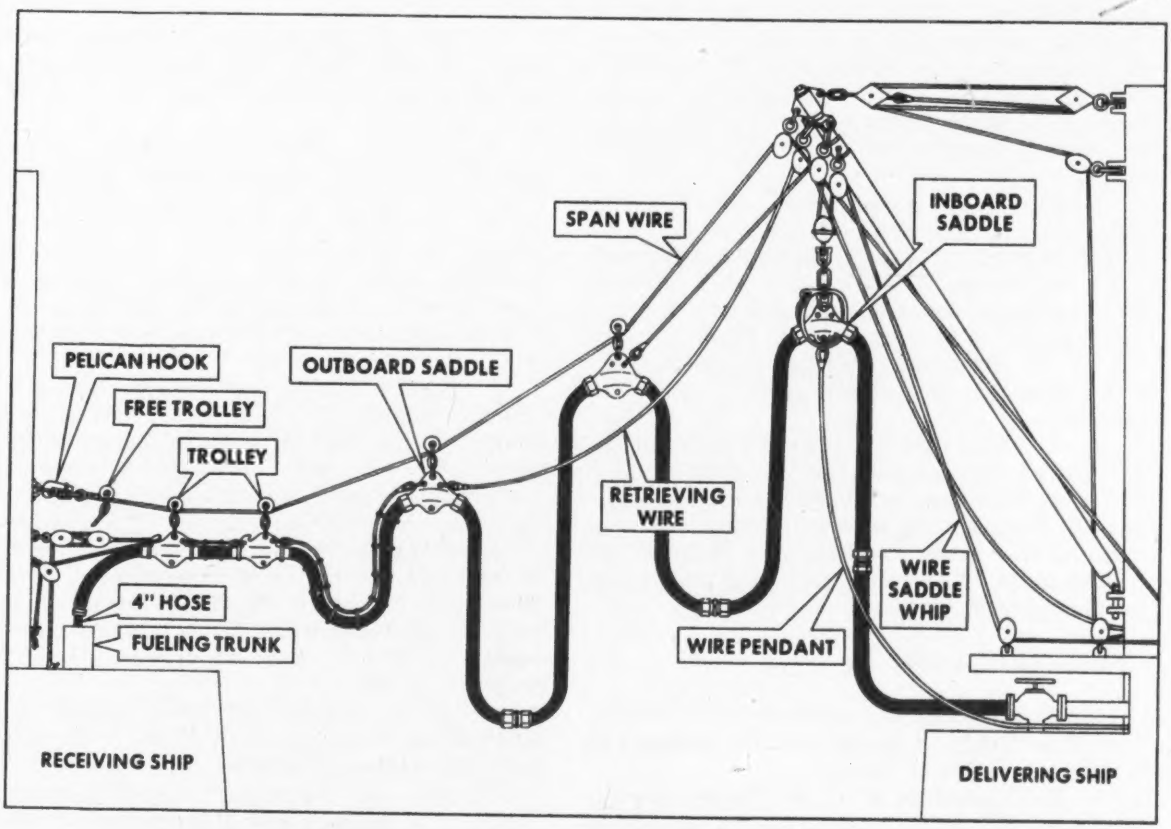

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Figure 13-13.—All wire Spanwire rig.

Government-owned fleet and other tankers acquired by MSTS; to arrange for tanker space in commercial shipping to meet the bulk POL (petro oil and lubricants) lift requirement of the Department of Defense with maximum efficiency and economy; and to recommend adjustments in the MSTS lift capability to conform to bulk POL lift requirements.

MSTS tanker operations are centrally controlled in Washington, D. C., except when specifically authorized otherwise, as in the case of small tankers assigned to operate in local areas. This central control is necessary because bulk petroleum requirements, product availability, and storage availability vary constantly.

Categories of Ships

MSTS utilizes two broad categories of ships to accomplish its mission: (1) Government-owned ships, and (2) chartered commercial ships.

1. Government-Owned Ships.—Government-owned ships may be sub-divided into two groups:

a. MSTS Tankers - These are designated as United States Naval Ships (USNS). They are owned by the Navy and include:

(1) Civil Service-Manned Tankers.—These are small tankers manned by Government civil service personnel and assigned to a local area, or special project, such as in Japan or for Arctic resupply. This is the major portion of the MSTS tank ship fleet.

(2) Contract-Operated Tankers.—These ships are assigned to steamship companies to operate under contract. The contracts are let on a bid basis and provide for reimbursement of cost-plus-fixed-fee. The USNS tankers under contract are manned by maritime industry personnel. They are public vessels of the United States entitled to the same courtesies, immunities, and privileges as any other ship of the Navy.

b. Fleet Oilers.—These are commissioned vessels of the Navy normally used for refueling the fleet at sea. Because of the operational requirements of the fleet they are used only when traffic volume exceeds the carrying capacity of MSTS tankers and commercial tankers cannot be obtained at fair and reasonable rates.

2. Chartered Commercial Ships.—These ships are privately owned and operated, but are under charter. They are chartered as follows:

a. Voyage Charter.—The ship is leased for a definite stated voyage at a fixed amount. The number used varies from month to month due to the fluctuating petroleum requirements and positioning of the MSTS government-owned tankers.

b. Time Charter.—The ship is hired for a specific period of time. MSTS operates the ship and pays the owner an amount based on a price per deadweight. The cost of this type of charter includes the time charter cost, bunkers, and port charges. The owner pays maintenance and overhaul costs.

Responsibilities of MSTS

MSTS has three major responsibilities which are of particular interest in ocean transportation of petroleum products.

1. Determination of Tanker Requirements.—MSTS is responsible for determining tanker capabilities required to meet bulk POL life requirements received from authorized sources, and arranging for shipment in accordance with policies and priorities of the Joint Chiefs of Staff and the Department of Defense. Recommendations are made on the acquisition of Government-owned tankers as required or reduction of tanker capabilities if petroleum requirements decrease. The need for chartering privately owned tankers is also determined.

2. Contracting.—MSTS negotiates, executes, and administers contracts with commercial operators for the operation of Government-owned tankers.

3. Control.—MSTS exercises direct control over the movement and deployment of all MSTS controlled tankers, supervising their utilization. MSTS advises on the need for alterations and improvements to tankers or the acquisition of new tankers of different types. Reviews of ship inspection and other reports are made and recommendations for improvement are provided.

Chartering

Commercial tankers are chartered to fulfill tanker requirements. The three main types of charters are bareboat, voyage, and long-term time charters.

1. Bareboat Charter.—A tanker bareboat hire is one under which the owner delivers the ship to the charterer for a period of time; vesting in the charterer most of the incidents of ownership. The charterer is responsible for manning, operation, and control of the ship. The cost under bareboat hire is the sum of bareboat charges, bunkers, port charges, operating costs, and repair and overhaul.

2. Voyage Charter.—A voyage charter is a contract whereby a ship is made available to the charterer for the shipment of cargo between given ports or ranges. The ship is committed for a single, repeat, or consecutive voyage over the same or different routes. The charterer provides the cargo and pays freight according to the route and amount of cargo carried. Owner pays all operating expenses, such as port charges, cost of bunkers, loading and discharging expenses, if not otherwise agreed, out of the freight revenue.

3. Time Charter.—Tankers under time charter are contracted for full use of the vessel for a designated period of time. The owner is responsible for operation, navigation, maintenance, and management of the vessel including crewing, fueling, storing, and husbanding. The entire reach and burden of the vessel is placed at the disposal of the charterer. The charterer has operational control, which includes providing loading, routing, and discharge instructions. The owner's income is the charter rate for the services of the vessel and crew, which is expressed in amount per day or month plus reimbursements for certain costs incurred for the account of the charterer as set forth in the contract.

4. Contracting for Operation of Government-Owned Tankers.—MSTS contract-operated tankers (USNS) are Government-owned tankers which are operated by steamship companies who have been awarded their contracts through normal competitive channels. They are under the administrative control of Headquarters, MSTS.

These tankers are officially designated MSTS tankers, in service (USNS) (contract operated). They are public vessels owned by the United States Government, and regarded as any other ship of the Navy.

Table 13-2—Tankers (U.S. Maritime Commission) Built World War II

Type	Speed in knots	Dead weight tons	T2-SE-A1 equivalent	Free board draft (fully loaded)	Cargo capacity in barrels, less 2% for expansion	Weight of cargo in long tons, at free board draft	Tons per inch of immersion, for overload	Pay load cargo in barrels at designated draft			
								Gasoline	Kerosine and diesel	Fuel oil	Average of all products
				Ft. in.							
T2	16.5	16,000	1.10	30 1-1/2	131,000	14,120	67.0	124,210	108,690	92,640	107,560
T2-SE-A1	14.5	16,600	1.00	30 2	138,335	14,690	67.0	129,230	113,070	96,380	111,900
T2-SE-A2	16.3	16,418	1.11	30 2	138,335	14,550	67.0	128,000	112,000	95,460	110,830
T2-SE-A3	16.3	16,400	1.11	30 2	138,335	14,550	67.0	128,000	112,000	95,460	110,830
T3-M-AZ1	15.0	17,910	1.12	30 4-1/2	149,540	15,750	67.7	138,630	121,300	103,390	120,040
T3-S-A1	14.9	16,388	1.01	30 0	131,000	14,330	66.4	126,100	110,340	94,050	109,200
T3-S-BF1	15.5	18,500	1.19	31 1	158,000	16,390	69.0	144,210	126,180	107,550	124,870
T3-S-BZ1	16.5	23,814	1.63	31 7-1/2	213,770	21,100	84.0	185,680	162,470	138,480	160,780
Z-ET1-S-C3	11.0	10,611	.485	27 9	63,530	8,200	48.6	63,500	63,120	53,800	62,460
T1-M-A1	10.0	1,528	.063	12 11	11,840	1,400	16.7	11,800	10,780	9,190	10,670
T1-M-A2	10.0	1,500	.062	13 0	12,460	1,370	16.7	12,040	10,530	8,980	10,420
T1M-BT1	11.0	4,166	.19	19 4	30,800	3,950	29.0	30,800	30,450	25,950	30,130
T1-M-BT2	11.0	4,200	.192	19 3	31,300	4,000	29.0	31,290	30,800	26,250	30,480

Each MSTS tanker displays in its pilot house a certificate signed by the Secretary of the Navy indicating its status as a public vessel. The contract precludes using the tankers in commercial service or for the contractor's own purpose.

The name of an MSTS contract-operated tanker is painted on the bow, port and starboard; on the stern; and on the port and starboard bridge name-boards. "U.S. Naval Ship" is painted above the name. Four bands are painted around the upper portion of the stack in the following colors: from top to bottom: black, haze grey, blue, yellow.

TRANSPORTATION REQUIREMENTS

In terms of tonnage and of cost, bulk petroleum products are the most important military petroleum cargo. It is the responsibility of MSTS to ensure that sufficient tankers are available to lift petroleum cargoes according to established schedules. The following discussion is limited to methods for computing the number of tankers required to make the required lifts.

Tanker Equivalents

To provide uniformity in determination of ship requirements for planning purposes, requirements are expressed in terms of notional ships. A notional ship is defined as a "theoretical or average ship in any one category used in high-level transportation planning." In the case of tankers, the T2-SE-A1 is used as the notional ship.

In determining tanker requirements, available tanker-types are converted to notional ships (T2 equivalents) by use of the following formula:

$$\text{T2-SE-A1 Equivalent} = \frac{\text{DWT} \times \text{SPEED}}{16{,}600 \times 14.5}$$

DWT is the abbreviation for deadweight tonnage which is the number of long tons (tons of 2,240 lb.) that a vessel will lift—including cargo, ships' personnel, supplies, etc.—when loaded in salt water to her summer freeboard marks.

Speed and other characteristics of merchant tankers built during World War II are given in table 13-2. Also shown in this table is the T2-SE-A1 equivalent for each tanker type. If a table of equivalents is not available, equivalents must be calculated by use of the above formula.

The following example is given to show the conversion of a T3-S-BZ1 tanker to T2 equivalents, using data from the table. Deadweight tonnage of the T3-S-BZ1 is, according to the table, 23,814. Speed is 16.5 knots. Thus,

$$\text{T2-SE-A1 Equivalent} = \frac{23{,}814 \times 16.5}{16{,}600 \times 14.5} = 1.63$$

If a table showing speed is not available, a short cut may be used if approximation only is desired to arrive at the average speed as follows:

Flag	Average speed if total DWT is 2,000 to 6,000	Average speed if total DWT is 6,000 or over
United States	14.4	14.5
United States owned, all flags	14.1	14.2
Western Hemisphere	14.0	14.1
ECA countries	12.4	12.5
British Empire, all flags	12.2	12.3
World	13.2	13.3

Number of Tankers Required

To determine the number of tankers required for a given task, the following generalized formulae are used: (1) for fuel oil, and (2) for gasoline:

1. FUEL OIL

$$T = \frac{QD}{3}$$

2. GASOLINE

$$T = \frac{QD}{4}$$

In the formulae, T stands for T2 Tanker Equivalents; Q for millions of barrels to be delivered monthly; and D for turnaround time in days, plus 14% for repairs. (Turnaround time is that period of time required by a vessel to make one complete round trip between its home port and its discharge port including complete preparations to resume the cycle.) The loading time of a T2-SE-A1 is considered to be 2 days and discharge time, 4 days.

For example, the number of tankers required to lift 600,000 barrels of Navy Special Fuel Oil at San Pedro, Calif., for discharge at Anchorage, Alaska (a voyage of 6 days each way), during a 12-month period, is determined as shown below.

An example showing the method of projecting tanker requirements in terms of T2 equivalents when consolidated POL requirements are known for any given fiscal period, taken as 12 months in this case, is shown in figure 13-14.

$$Q = \frac{600{,}000 \text{ barrels (for 1 year)}}{1{,}000{,}000 \text{ (to convert to millions of barrels)} \times 12 \text{ (to give figure for 1 month)}} = 0.05$$

$$D = (2 \text{ days} + 4 \text{ days} + 12 \text{ days at sea})\ (1 + 14\%) = 18 \times 1.14 = 20.52$$

$$T = \frac{QD}{3} = \frac{0.05 \times 20.52}{3} = 0.342$$

SOURCE OF LIFT	DESTINATION OF LIFT	PETROLEUM IN BBLS BLACK	PETROLEUM IN BBLS CLEAN	DAYS TURNABOUT	T2 EQUIV. REQD. BLACK	T2 EQUIV. REQD. CLEAN
U. S. West Coast (San Pedro)	Alaska (Anchorage)	600,000	800,000	18	.342	.342
	Hawaii (Pearl)	900,000	800,000	19	.542	.361
	Marianas (Guam)	400,000	100,000	37	.469	.088
U. S. Gulf (Houston)	U. S. East Coast (Norfolk)	2,000,000	800,000	16	1.013	.304
	United Kingdom (Thameshaven)		700,000	36		.599
		600,000	500,000	39	.741	.463
Persian Gulf (Bahrein)	Japan (Yokohama)	3,000,000	2,800,000	44	4.18	2.926
	Marianas (Guam)	900,000	400,000	42	1.197	.399
TOTALS		8,400,000	7,000,000		8.484	5.482
GRAND TOTAL Clean and Black Ships Required					13.966T2 Equivalents.	

*NOTE: Total ship requirements are reported to the nearest whole number, taken as 14 in this case.

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Figure 13-14.—Example showing method of projecting tanker requirements in terms of T2 equivalents when consolidated POL requirements are known for any given fiscal period, taken as 12 months in this case.

CHAPTER 14

FUEL DEPOT OPERATIONS

The normal operations at a Navy fuel depot include the receipt, storage, and issue of liquid petroleum products. The term "fuel depot" refers to any of the Navy's various fuel facilities. A fuel facility at a continental naval activity is shown in figure 4-1.

The principal products handled in bulk at Navy fuel installations include any or all of the following: Navy special fuel oil, diesel fuels, motor gasoline, aviation gasoline, jet fuel, and several Navy symbol lubricating oils. In addition, fuel depots may handle other bulk products and packaged fuel or lubricants, either in drums or smaller containers.

Fuel may be received by ship, barge, pipeline, tank car, or tank truck.

FACILITIES

The largest part of a Navy fuel depot is devoted to the tank farm area which is composed of bulk storage tanks and related facilities, such as pipelines and pumps. Usually drum handling facilities are separate from the tank farm area and may include not only storage space for drums, but drum filling and reconditioning equipment. In addition, there are various facilities for receiving and dispensing fuel. Of these, water front facilities are of special importance and are described under the section on water front operations.

Location

Some depots are attached to or are part of an operating base. Others are isolated from other military activities. In either case, many factors must be considered in selecting a site for a fuel depot.

Adequate space must be available, not only for the tanks themselves, but for proper spacing between tanks. For safety reasons, the site should be remote from populated areas and from congested industrial areas. Nevertheless, the depot must have easy access to transportation facilities, including water, railroad, and highway transportation facilities.

At advanced bases, the strategic value of the location is a primary consideration. The depot must be located so that it can supply the various units of the Armed Forces at all times, even though normal transportation routes and facilities are temporarily paralyzed. Moreover, the physical characteristics of the terrain must be considered for ease in providing cover and protection.

From a construction standpoint, both the topography and the character of the soil must be taken into consideration. Fairly level topography is desirable, since surface tanks require level foundations. If fairly level terrain is not available, extensive excavations are necessary. The ground should be firm so that tanks will not shift. Certain types of soil—particularly alkaline or acid soils which are corrosive to metals—should be avoided.

Pipeline Systems

The pipeline systems may be divided into three basic types: single line, double line, and loop. Combinations of the three may be found.

A single line system consists of one line for each product from tankage to dock and to tank car and tank truck loading and receiving racks. In a loop system, tanks and possibly pier risers are connected to a complete loop so that two paths for product transfer are provided. Double line systems are installed where topography and arrangement of facilities make looping less practicable. This system may include duplicate connections to each tank, tanks connected alternately to each line, or cross connections of main lines for tank accessibility. Each system is provided with one or more types of valves and fittings.

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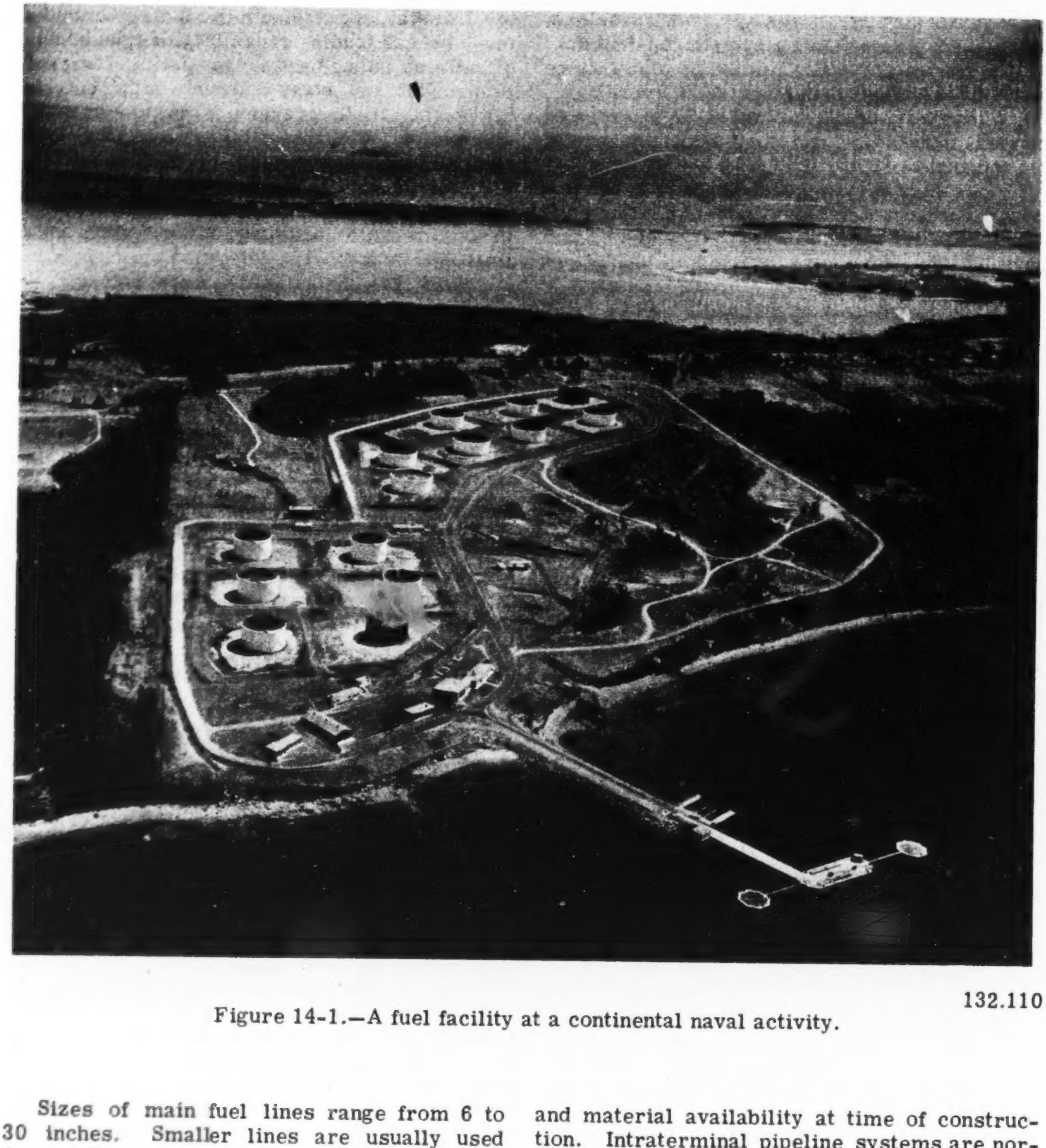

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Figure 14-1.—A fuel facility at a continental naval activity.

Sizes of main fuel lines range from 6 to 30 inches. Smaller lines are usually used for auxiliary service such as bypass, pressure release, gage lines, engine feed lines, temporary installations, and the like.

Pipes also vary by weight or wall thickness according to the needs of the installation and material availability at time of construction. Intraterminal pipeline systems are normally designed to be operated at pressures near 100 psi and are frequently called low pressure systems. Interterminal pipeline systems are used to connect two or more bulk terminals, and are designed to be operated at pressures up to 1000 psi or more for welded lines and 600 psi or more for coupled lines. They are often referred to as high pressure systems.

Safe working pressures are design problems and are considered during system construction. The pressure is usually limited by pipe fittings and valves rather than by pipe. In every case, the allowable working pressure is established at each installation and posted for guidance of all concerned.

Pipes also vary in kind by type of construction. The more common varieties of pipe encountered are welded steel, seamless, and spiral weld. Pipe most commonly used is of welded steel construction. Seamless pipe is usually limited to tubing, while spiral weld pipe is usually found in temporary installations such as military portable pipelines.

Pumps

The number of pumps and other facilities is governed by the size and type of storage accommodations. The simplest type may have no booster pump, the product being delivered directly to storage by tankers and transferred from storage to dock by gravity or by pumps located at the individual tanks. However, at a large depot, covering considerable area or elevation, one or more pumps may be provided to assist in the receiving of cargoes, (usually from tankers) to provide for delivery of product from tanks, and also for accomplishing transfers between tanks.

The types of pumps most generally used throughout the naval liquid fuel distribution system are: centrifugal, axial, reciprocating, and rotary. Generally, the pumps will be driven by constant speed electric motors, although other sources of power are sometimes provided such as diesel or gasoline engine drive, and steam turbine drive.

Receiving and Issuing Facilities

Fuel pipelines are provided for receiving the product in bulk from a connection made to a commercial pipeline, from a ship or barge moored at an unloading dock, or from an unloading header at a tank car loading rack. If necessary, a booster pump is provided along this fuel line between the receiving point and the storage center, for the purpose of boosting pressure in the line. Pipeline flow may be reversed in operation to effect issue of product.

In any type of receiving or issuing facility, provisions are made for electrically grounding ships, barges, or tank cars before and during the transfer of petroleum products. Grounding for tank car loading racks includes the bonding of railroad sidings and the insulating of trackage to prevent any stray currents from entering the plant or to prevent formation of static electricity. If transfer takes place from commercial pipelines, the line is separated from the storage center piping by an insulated joint. This prevents a line provided with cathodic protection from draining current from plant lines and tanks. The joint also prevents stray currents in the pipeline from entering the plant.

If unloading is to be done at a regular tank car loading rack, facilities are provided for unloading cars from bottom outlets. Tank cars are loaded overhead through submerged-type loading arms from swing-type connections and risers on the tank car loading rack. Trucks are loaded from truck loading racks or from separate truck loading stems located along roadways and at a safe distance from normal traffic patterns.

On docks, hose supports are provided to prevent wear and tear in the unloading hose and to permit easy handling of the hose. Pans are also provided under all unloading connections to catch any drip or slight spill.

Auxiliary Facilities

Auxiliary facilities at military fuel depots differ widely, although most depots have a full complement of equipment such as communication facilities, firefighting equipment, cargo hose, water transportation, strainers, diesel fuel filters, and equipment for confining and recovering oil spilled on the water. Many depots also have facilities for receiving ballast from tankers or ships.

Most depots are furnished with at least a minimum of testing equipment while others are equipped with complete laboratory facilities for testing petroleum products. Some depots also have contaminated oil recovery systems.

Utilities such as water supply, salt or fresh water for fire protection, sewage disposal, and power supply will vary in military fuel depots. Frequently, electric power is supplied by public utilities. This power is often supplemented by a source of power at the military activity. Sewers discharging oily water are kept separate

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from sanitation sewers because oily waste and sewage readily combine to form an emulsion of refractory quality. The installation of gravity water/fuel separators at outfalls of drainage ditches is necessary to eliminate oil contamination of navigable waters, in the event of oil spills or tank overflows.

ADMINISTRATION

Since the various fuel depots operated by the Navy differ in size, arrangement, and activity, the functional organization varies. Moreover, the organization of an individual depot must be sufficiently flexible to meet changing operational requirements. For example, some fuel depots, installed largely for reserve and emergency purposes, may be inactive over long periods of time. At these, the responsible commanding officer decides how complete an operating organization must be maintained. If the depot remains inactive, all but the necessary skeleton organization may be assigned to other duties nearby, being returned for temporary duty at the depot from time to time.

Even at an active depot, operations may be irregular. Small issues to barges and harbor tenders may constitute a regular daily business; large receipts from tank ships and large issues for off shore delivery, requiring extra help, may be only occasional. The organization, therefore, should be such that men can be shifted from one duty to another as required.

Typical Organization

The functions of a typical fuel supply depot fall into two distinct areas: control, which is concerned primarily with the administrative aspects of inventory control; and material handling, which is concerned with physical receipt, storage, and issue of petroleum product.

Inventory control, which is a subject in itself, is covered in the BusandA Manual, volume II, and therefore is not covered here. Material handling is an operational function and it is this operational area with which this chapter is primarily concerned. A more complete description of these operations appears in the Military Standardization Handbook Petroleum Operations, MIL-HDBK-201A.

Personnel

The exact titles of persons at fuel depots vary from place to place, owing to the difference in the nature of local organizations. However, nomenclature used here indicates the types of jobs to be performed at a typical fuel depot.

At a large activity a supply officer will be the authority in direct charge of fuel receipts and issues. He is responsible for the receipt of fuels including: (1) making the necessary arrangements for the delivery of fuels; (2) handling the necessary accounting records; (3) taking all steps necessary to assure himself of the quality of material received; and (4) taking all steps necessary to assure himself of the quantity of fuel received, and witnessing all tank and/or compartment gages, water gages, temperatures, and the like.

At a fuel depot the individual having direct charge of all the fuel facilities is generally called the fuel officer, if he is a naval officer; if a civilian, he is usually called the superintendent.

The person who works primarily in tank farm operations is frequently called a gager. He must be especially skilled in gaging tanks, taking temperatures, and drawing samples, but he also supervises the opening and closing of valves and keeps or supervises the keeping of the logs and records. He should be able to make simple identification tests to ascertain the quality of the product and should be able to perform the functions of the pump operator as required.

The operations supervisor of the tank farm is directly responsible for the operation of the tank farm. Through his supervisor, he must keep informed of all pumping operations, the amount of cargo to be received, discharged, or transferred, tanks to be used, and such other information as is necessary for making advance preparation for pumping operations. Before any operation is started, he must prepare a written schedule showing exactly what tanks and lines are to be used, the sequence of operations to be followed, the estimated rate of filling, and the approximate time when switches will be made. During operations, he checks the transfer of products against the schedule and corrects the schedule accordingly, informing his supervisor of all deviations from the original plan. The operations supervisor informs the dock watch of all proposed tank switches and of the exact time when a switch is to be made. He causes a log to be maintained containing a complete running record of all tank and transfer operations. It is also the responsibility of the operations supervisor to ensure that all personnel assigned are adequately instructed in operations and safety practices and that all such instructions are followed. Finally, he must ensure that storage tanks are gaged and sampled as required; that all required reports are properly prepared and submitted as scheduled; and that all orders issued by higher authority are followed.

A helper usually assists in opening and closing valves, starting and stopping pumps, operating heaters and clarifiers, and doing any other necessary work, under the supervision of the gager.

A title such as petroleum inspector, is used to designate the person whose principal duties are the taking of samples, inspection of cargo transportation equipment such as trucks, tank cars, barges and tankers and the testing of samples. He is also responsible for determining the quality and quantity of products received or issued. The inspector is usually assigned to the depot and is responsible to the fuel officer for the depots quality surveillance program. When an inspector or other authority outside the depot is called in to help arbitrate points in dispute or to aid a board of investigation, regardless of the agency to which assigned, he is referred to as a referee inspector.

The man supervising any given operation—such as an issue or receipt of cargo—may be called the watch supervisor. Sometimes, however, his actual title may be dispatcher or he may, in effect, have the powers of a superintendent reporting directly to the fuel officer.

The wharfman under the supervision of the watch supervisor or operations supervisor, performs operations at the pier, such as opening and closing valves, keeping the log, maintaining telephone or other communications with the pump house, tank farm (field) and ship, and witnessing gages. He should be able to take or direct the taking of samples as well. The pump operator is the man in charge of the pump operations. He may also operate fuel oil heaters and diesel oil strainers and filters and may, as required, perform the functions of the gager or wharfman.

PIPELINES

Since detailed information on pipeline operation is provided by the Military Standardization Handbook, Petroleum Operations, previously mentioned, no discussion is included here. Aside from actual pipeline operations, there are two considerations relevant to petroleum logistics which deserve mention. They are: the standard method for identifying products carried by pipelines, and certain pipeline pumping data.

Identification Method

Exact identification of petroleum products in each piping system is mandatory and is made by means of lettered titles stenciled on the pipe adjacent to the control valve. The stenciled title identifies the contents by nomenclature and symbol. Titles are lettered on the pipe in such a manner as to be clearly visible from operating positions. The use of stencils with standard size letters is recommended but for piping smaller than 3 inches in diameter, metal flags or signs, securely fastened to the pipe, may be used.

In addition to the stenciled title, a standard method for identifying petroleum products in pipeline systems by means of color bands has been established. The purpose of this method of identification is to promote greater safety to personnel and to lesson the chance of error or confusion in times of emergency. It is emphasized, however, that the exact title, stenciled on pipelines, is the principal identifying feature and that the color band or bands should not be relied upon as the sole means of identification.

The method of identifying petroleum products in pipeline systems by color bands was established by Military Standard 161B. This method of identification is applicable at all installations of the Department of Defense where camouflage or concealment is not required. It applies to all piping systems carrying petroleum products. A piping system is considered to be any pipe or part thereof used to convey liquid petroleum products and includes tank car and tank truck loading and unloading connections, storage tank valves, pump manifold and valves, cross country pipelines and booster pumps, oil tanker hose connections and valves, fill stems at aircraft fueling pits, hydrant refueling systems and other fuel outlets. It is not applicable to aircraft, ships, power plants, and heating systems.

Yellow is assigned as a primary warning for all flammable materials in accordance with provisions of the basic color code for compressed gas cylinders and pipelines (MIL-STD-101A). Petroleum products are considered as falling within this classification of materials. Under no circumstances may colors other than yellow for warning, and black and white for identification, be assigned to petroleum products. Special attention is invited to the color red, which is assigned exclusively for the use of fire protection materials and equipment. All other piping systems not carrying petroleum products employ the warning colors assigned in MIL-STD-101A to the particular material.

Bulk petroleum products generally used in the military system have been classified and segregated into groups to facilitate the ready identification of product groups. This method establishes, defines, and assigns a yellow band or series of bands for recognition to each of six groups of similar-type products in a distinctive and conspicuous manner as a visual aid and supplement to the written identification. These groups are aviation gasolines, automotive gasolines, jet fuels, distillates, heavy fuel (black) oil, and lubricating oils.

The yellow bands separate and distinguish the various groups of petroleum products. Because of the infrequency of their use, bands have not been assigned to lubricating oils but a flag or sign may be employed. Each flag or sign must have a yellow border, a minimum of 3/4 inch in width.

When a single pipeline is used for transporting more than one product, a flag or sign identifying the product in the line at the time may be used in lieu of or as a supplement to the wide yellow identification band and nomenclature as illustrated. The yellow band in these instances is at least 36 inches in width. An arrow painted in yellow may be used to indicate the direction of flow of the product in the line. If used, it appears adjacent to the title and band(s).

In instances where a piping system is buried or inaccessible and only a valve stem and wheel are exposed, a metal flag or brass disk is used as an aid in identifying the product in the line. The flag post may be permanently fixed to the pipeline or in concrete adjacent thereto. The brass identification disk is placed on top of the valve wheel under the nut on top of the valve stem. In concrete pits and under similar conditions where space will not permit banding and stenciling of the pipe, the vertical band(s) is painted on the wall adjacent to the pipe. The name of the product is stenciled horizontally in white-over-black across the band(s).

Logistic Data

This data provided by figure 14-2 may be used in petroleum operations planning. The pressure shown is that which is required to pump petroleum products through pipelines over level ground. The curves are plotted to 7 ft/sec velocity. In logistic planning the data is useful, for example, in estimating the number of barrels of a given product which can be moved per hour through pipeline of various diameters.

DRUM FILLING, RECONDITIONING, AND PRESERVATION

Drum filling with gasoline, kerosine, diesel fuel, and lubes is frequently encountered. At overseas installations and continental activities where commercial facilities are unavailable, drum reconditioning and preservation plants may be operated by the Navy. Moreover, large quantities of packaged products are stored at supply activities. The proper performance of these operations is necessary to: (1) ensure maintenance of product quality; (2) ensure safe operations; (3) reduce operating costs; and (4) ensure full utilization of steel, equipment, personnel, and product. Because a wide variety of equipment and operating conditions are encountered, only general procedures are covered here.

Drum Filling Operations

Filling operations may be carried out with either permanent or temporary equipment. Either cans or drums may be filled. In any case, no filling can be done until the filling equipment and procedures are checked by the fuel officer or his designated assistant, and until an inspector approves procedures, containers, product, lines, and other equipment.

When directed by the fuel officer to transfer bulk petroleum products into clean empty drums, the following principles and practices are followed:

1. All drums to be filled are inspected for moisture, rust, and holing, for tight bung fittings, and for tight, perfect gaskets. Any

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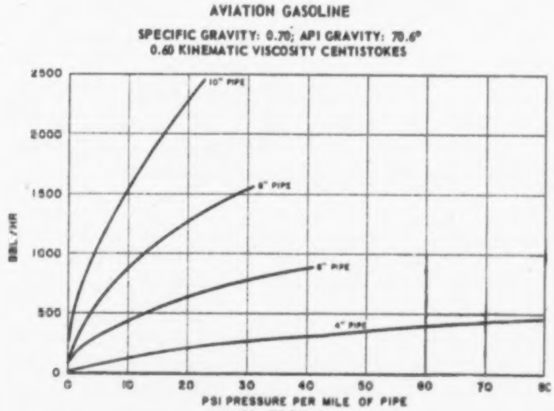
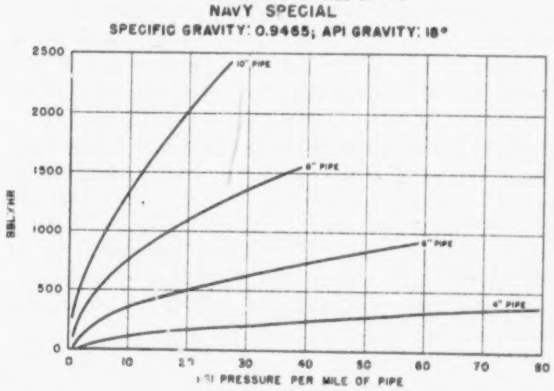
drums which are found to contain liquid, moisture droplets, pitted or scaled rust, or any foreign material such as gravel, sand, grease, and the like are not used for filling but are segregated for further cleaning or reconditioning as required.





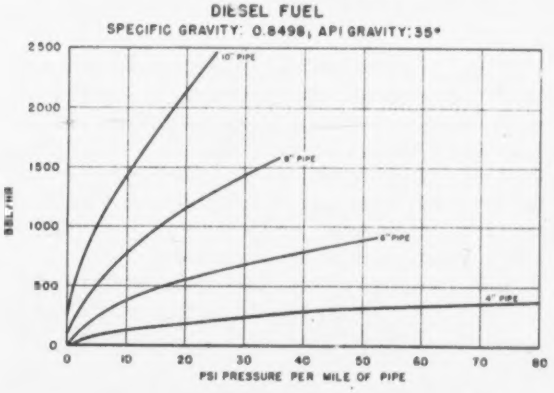


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Figure 14-2.—Pipeline data.

2. Filling of drums is not authorized at any site where grounding cables and connections are not installed or are not in good condition. Grounding equipment is periodically inspected by fire prevention, safety, and electrical personnel for satisfactory construction, installation, and performance.

3. No filling operation is permitted to be unattended or unsupervised at any time. Individuals employed in filling operations must ensure that: (a) equipment is functioning properly; (b) product is flowing smoothly; (c) only spark-proof tools are used in the area near the drum filling installation; (d) no welding or other hot work is being done in the vicinity while filling is in progress; (e) fire-fighting extinguishers and equipment are available and properly located; (f) no automotive or other internal combustion engine equipment is being operated within 100 feet of the filling location unless these vehicles are directly concerned with the movement of drums to or from the filling location. To ensure that no spills or overflows occur, employees must not leave the filling equipment while a drum is being filled.

4. Each 55-gallon drum is filled with 53 gallons of fuel. Care must be exercised that no more than 53 gallons of product are drummed since space must be left inside the drum to provide for changes in volume due to temperature variations.

5. After filling is completed the bungs of the drums are replaced, tightened, and secured with spark-proof drum wrenches. New gaskets are used whenever tearing, deterioration, or warping of the original gasket is observed. A seal-type closure is also affixed to prevent tampering with the contents of the drum before delivery to the consumer.

6. All drums are identified by stenciling immediately after filling in order to avoid errors in product identification.

7. Filled drums must be carefully handled to prevent damage to the drums, friction-caused sparks, and injury to personnel. All personnel handling filled drums should be trained and supervised to ensure careful handling in transit to the storage sites, loading into trucks, barges, and freight cars.

8. Special precautions must be taken when lube oil is being drummed from bulk shipments or storage, or being decanted for bulk delivery. Such precautions are necessary in order to maintain the quality of the lubricant.

Drum Reconditioning and Preservation

Drums which are not returnable to contractors but are suitable for reuse may be reconditioned or represerved. Drums lying in storage at primary stock points for extended periods are periodically checked to determine whether representation is required. In the interest of conservation and to maintain an adequate supply of ready-issue drums for regular or planned requirements, drums may be reconditioned if the costs involved can be justified.

Reconditioning of drums consists of a complete exterior and interior reconditioning, including removal of interior rust, chime work, removal of dents, painting the exteriors, testing for leaks, inspection of plugs and bungs, applying rust preventive oil, and cap sealing of bung and plug holes.

Representation of drums pertains to cleaning and repainting the exteriors, steaming out and degassing the drum interiors, testing for leaks, cleaning of flanges, inspection of plugs and bungs, applying rust preventive oil, and cap sealing of bung and plug holes.

All used drums are screened carefully to determine whether they can be used again. Some are suitable for reconditioning or representation. Others, having certain specified defects, must be rejected and disposed of in accordance with BuSandA Manual. All reconditioning of metal drums must be done in accordance with current military specifications.

WATER FRONT OPERATIONS

The fuel officer and his principal assistants should be familiar with established rules and regulations governing water front activities. Water front personnel are the persons responsible for ensuring proper conduct of all phases of the fuel operations and ensuring compliance with local and Navywide regulations. They should not only know the regulations governing shoreside personnel but should be thoroughly familiar with customary rules for ships. It is essential that all safety precautions be observed.

Equipment and Facilities

Bonding.—Electrical bonds and grounds between pipelines, ships, and equipment are common requirements at all fuel depots, especially if volatile products are to be handled. These electrical bonds and grounds are designed to prevent the occurrence of a spark which might ignite combustible vapor and air mixtures. Such a spark may result from an accumulation of static electricity or may be due to stray electric currents.

When small issues of gasoline are made through an open hose nozzle, an electrical bond is required between the nozzle and the tank into which the issue is delivered.

The bonding cable must be connected to the ship before the hose connection is made and it must not be removed until after the hose is disconnected. As a further precaution this bond is closed and opened through an explosion-proof single-pole ground switch which is located at each manifold on a pier but at sufficient distance from the hose connection to ensure that no spark occurs except in the switch, which of course should not be open when the hose is connected. This is a stray current bond designed to prevent sparks between the ship, the pipelines, and the hose connections.

The end of the bonding wire which is to be connected to the ship is equipped with a C-clamp or other similar device having sharp prongs or teeth to ensure a positive connection between the end of the cable and the metal surface of the ship which may be coated or painted.

Safety Tools.—The use of standard or approved nonsparking tools for all dock operations is good practice. Such tools must be carefully stored and handled to prevent loss.

Hose and Fittings.—The hose should be tested under hydraulic pressure to one and one-half times the normal working pressure (not to exceed 150 psi) every 3 months unless it is out of service. Hose stored without use for more than 3 months must be tested before use. Hose that is stored should be protected by a brass screw cap fastened to the coupling or by a wooden plug at each end of the hose. These devices prevent foreign matter from entering and causing trouble in pump impellers and contaminating petroleum products. New hose should be tested when received. If any hose is kinked or subjected to any unusual strain or if visual defects appear, it must be tested before use. Tests should include checks to ensure that the internal hose bonding is intact. The date of all tests should be stenciled on the hose in chronological sequence.

Firefighting Equipment.—Firefighting equipment on piers usually is of a portable type. During most operations, especially when volatile products are being transferred, fire hoses on ship and shore must be located near the scene of operation and readied, under pressure, for immediate use. Extinguishers, usually in a bank arrangement, should be immediately available, and yet located at a safe distance from the most likely source of fire. Wharfmen should know how to operate all standby portable extinguishing equipment.

Communications.—Adequate communications, preferably telephones (which should be spark-proof type), should be available on piers, to contact pump rooms, or control rooms. Walkie-talkies may be desirable in some instances, and may be used if they are a nonsparking type. A source of communication to ship's pump rooms should also be available to the pier force while operations are in progress.

Hose Handling Equipment.—Derricks are commonly provided on piers for handling hoses which are over 4 inches in diameter. (One method of rigging a hose is shown in figure 14-3. At certain locations small movable cranes may be used. Such equipment is generally selected to meet the requirements of individual installations.

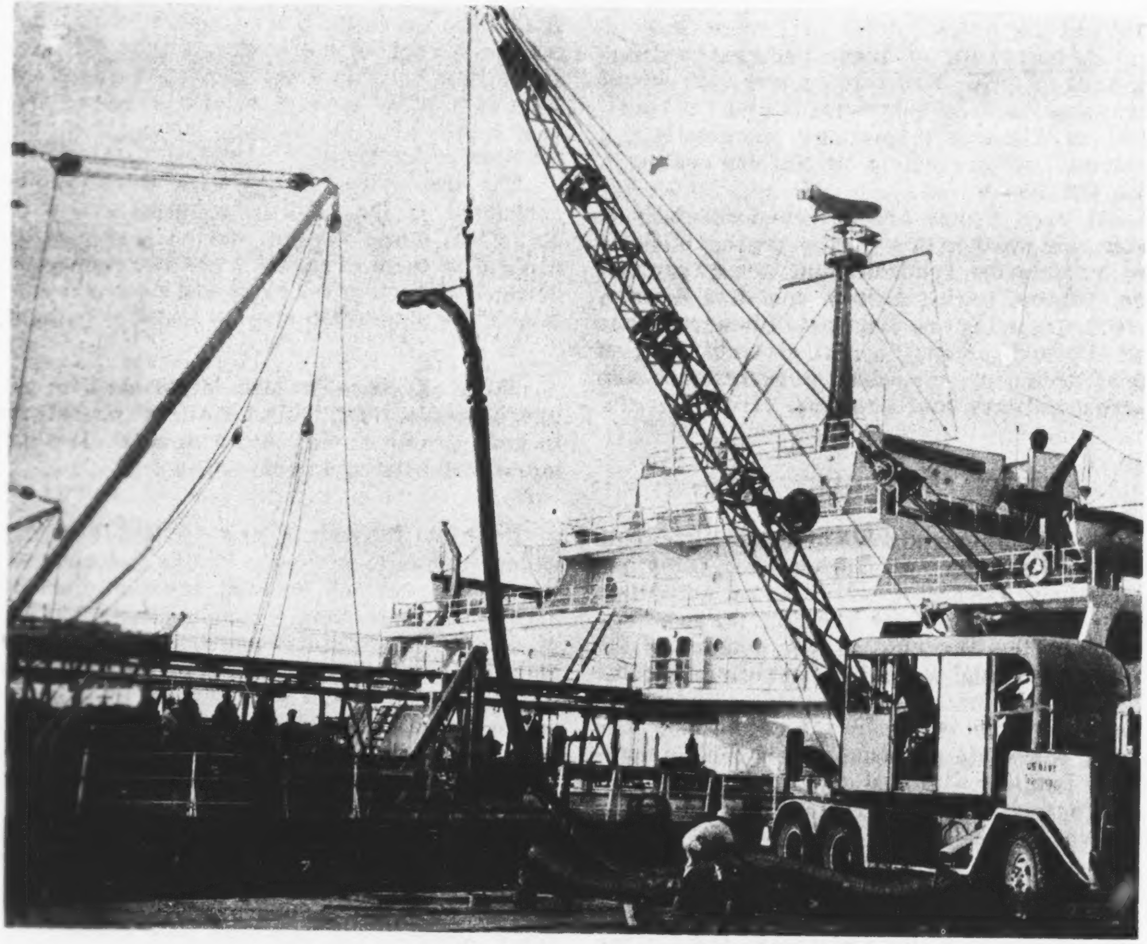

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Figure 14-3.—Rigging a hose at a fueling depot.

These facilities are normally needed to suspend hoses and to allow for movement of the ship during transfers. Hose dollies are very useful for moving and supporting hose on docks.

Gaging Equipment.—Equipment used for gaging on piers is the same as regular gaging equipment.

Sampling and Testing Equipment.—Equipment used on piers for sampling and testing is the same as that used in the laboratory.

Clarifiers and Preheaters.—Depots issuing diesel fuel oil are normally provided with clarifiers for removing water and sediment. A clarifier consists of a leaf strainer followed by an absorbent element such as fuller's earth. Preheaters may also be provided for raising the temperature of the oil to the temperature required to realize the rated capacity of the equipment.

Duties of Fuel Depot Personnel

A regular inspection must be made of the dock and the facilities provided at the dock to ensure that all lines and valves are so located that they will be easily accessible and protected from external damage, that at least one suitable small boat or launch is available and accessible at all times for emergency use, and that a sufficient number of cork ring buoys with life lines attached or other life preservers are located at convenient and designated points. The fuel officer is responsible for ensuring that emergency ladders and necessary emergency fire equipment including portable extinguishers, fire hose, blankets, sand boxes, or filled water barrels, and the like, are available and on the wharf.

Before transfer operations, the fuel officer or the superintendent must see that the cargo hose is of the type required for the product to be handled, that it is provided with a built-in grounding conductor, and that it is in good condition. He must check all wharf lines to see that they are properly bonded to a ground placed below low water level at a point near the unloading connections, and also at the shore line if the wharf approach is a long one.

The time of the arrival of a tanker which is to unload and the kind and amount of petroleum product to be received should be known beforehand, if permitted by intelligence restrictions, and all arrangements for its receipt made 24 hours in advance if possible.

If feasible, the fuel officer or superintendent should prepare and issue written orders to designate: berth to be used, pipelines to be used, number and sizes of hoses to be connected, tanks into which cargo is to be received, pump house and pumps to be operated; number of samples to be taken, where and when; and tests required.

These orders should describe specifically any line cleaning or displacement operations to be performed and any blinds to be inserted or removed as well as the locations where samples are required. Necessary gaging and sampling of lines and tanks should always be performed in advance of arrival.

The fuel officer should designate the posting of regular personnel and should arrange for any extra labor needed to handle lines and connect hose, as well as for special assistance such as tug or pilot if required by the ship. All gear necessary for mooring the ship and receiving the cargo should be ready for use on the wharf.

Before the ship is moored, the wharf pipelines should normally be filled. It is impossible to secure an accurate measurement of receipt unless the lines are completely full, or completely empty with the exact line volume known. However, it is permissible to empty certain parts of the line system by gravity or by pump between the opening and closing gages if appropriate volume corrections are made.

The fuel officer or the superintendent normally takes charge of dock operations when any large vessel is being moored or when large transfers are started and stopped. If JP-4 fuel or gasoline is transferred, the fuel officer or superintendent should personally supervise the critical points of the operation and be available during the entire operation.

The fuel officer may also visit the tanks, pump houses, and other parts of the property where the most important operations are being performed. He must ensure that all logs are kept, necessary samples taken, receipts and invoices executed, and safety precautions observed. The fuel officer must keep the superintendent informed of his whereabouts at all times so that he can be reached immediately in case of an emergency. Furthermore, it is the fuel officer's responsibility to escort the ship's officer or inspector to the tank field when gages and samples are to be witnessed. It is the duty of the fuel officer, superintendent, and wharfman, as well as the guard, if there is one, to see that security regulations are observed. Also, if

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any hazardous condition develops during operations, the fuel officer or superintendent must immediately clear the wharf of all persons not absolutely essential for the continuance of operations.

Although it is the responsibility of the ship's officer to provide a hose watch when cargo is being discharged to shore tanks, the fuel officer, superintendent, or wharfman should not assume that the required hose watch has been provided until notified of this fact. If the hose watch has not been provided by the ship's officer, the fuel officer or superintendent should provide a watch and immediately notify the ship's officer of this fact.

When vessels are being loaded, the depot provides a dock hose watch to stand by at all times. It is the responsibility of the hose watch to close the wharf valve and to order pumping or gravity transfer stopped if the ship requests it, if any oil spill or serious leak is observed, if oil is seen on the surface of the water, or if any other circumstances warrant it. Failure to establish a hose watch is one of the most dangerous breaches of safety rules. (Hose breakage, either at Navy or commercial docks, has been a rare occurrence but has happened, with disastrous consequences, when gasoline was being transferred.) At least one experienced and responsible wharfman, in addition to the dock hose watch, should remain on duty at the dock during the entire period of bulk cargo transfer.

No one is permitted to leave his post of duty during cargo transfer until he is properly relieved. Personnel responsible for making entries in the logs or field books must complete their records and must review them with their relief personnel until mutual understanding is reached. All matters of possible importance should be reviewed until the man coming on duty is fully aware of the situation and the exact condition of all facilities being employed.

Duties of Ship's Personnel

The responsibility for safe mooring rests with the ship, but the shore personnel must assist in every way possible. Port officials or the fuel officer must not allow a vessel to moor if any serious and unusual hazards are apparent. The position of the ship should be spotted by the fuel officer or superintendent in the proper location to make connections in accordance with previous orders and arrangements. The terminus of a mooring line at bollards should be a manila line that can be cut with an ax in an emergency, unless other means of emergency release are provided. In the absence of local regulations to the contrary, it is recommended that no ship be allowed to moor adjacent to or within 200 feet of a ship which is transferring bulk cargo unless the port officials, fuel officer, and the officer of the ship transferring cargo agree that it is safe. If there appears to be a hazard, cargo transfer must be interrupted until the second ship is safely moored. (There is always a special hazard if a volatile product is being loaded; therefore, transfer operations should be stopped until the second ship is moored.)

The responsibility for the safe handling of the ship's facilities rests with the ship's officers. In general, the fuel officer of the depot and the superintendent assume that the ship is duly observing her obligations unless surveillance discloses an unsafe condition. If the ship should appear to be following an unsafe practice, the cargo transfer or issue is stopped at the direction of the fuel officer, or his representative, until an agreement can be reached with the ship's officer.

During the entire time of bulk oil transfer, there will normally be at least one deck officer and one engineer officer on duty on the ship. Obviously, this rule, applicable to large ships, is to be interpreted to suit the actual personnel in issues to small carft.

All personnel involved in fuel operations should always be alert for hazards and call them to the attention of the proper personnel for corrective action.

Personnel required for performing hose handling and operations aboard ship are those required by standard ship or naval practices. It is generally the responsibility of ship personnel to perform all actual connecting and disconnecting of the hose couplings aboard ship and to be responsible for safe completion of such functions. The depot fuel officer, however, should review and inspect conditions both ashore and aboard ship before operations commence, to ensure compliance with good safety practice.

As previously mentioned, when cargo is being discharged from a ship to shore tanks, it is customary for the ship to provide a hose watch to stand by at all times to raise or lower the hose, to watch for strains or chafing of the hose, to close the ship's valves, or to signal the pumper in the event of emergency. The hose watch must observe closely the pressures on gages attached to the wharf risers and ship connections.

Importance of Quality Surveillance

The importance of quality surveillance and the alertness of all hands concerned in the transferring of petroleum products cargoes cannot be overemphasized. Although it is the direct responsibility of the petroleum inspector to check all operations, each member of the operating force is required to report immediately any deviation or change in flow or pressure that occurs. It is equally important that checks and tests be made during the transfer of products as well as at the beginning and ending of operations.

Night Operations

Cargo transfers at night involve increased hazards and should therefore be permitted only when this procedure cannot be avoided. Night loading of volatile fuels is especially hazardous and requires that thoroughly adequate vaporproof flood lighting be provided. During night operations, the entire working surface of the wharf and the deck of the ship should be lighted by floodlights if possible.

All personnel must be provided with approved safety flashlights, or electric lanterns, and must carry them, ready for use, in case of failure of general illumination.

Special precautions must be observed in topping off tanks whether they are the ship's tanks or shore tanks. This operation should be conducted at a safe speed—which is less, usually, than that permitted during daylight hours—under the direct supervision of the ship's officer and the superintendent.

During night transfer, especially when loading or fueling vessels, both the ship and the fuel depot should assign a man for continuous patrol of the wharf and ship to watch for any hazardous condition such as leaks, overflow of tanks, and appearance of oil on the surface of the water. In addition, one or more men should be assigned to patrol the shore pipelines, if any hazard is thought to exist. Such hazards might be exposed lines; places where oil from leaks might enter the harbor, railroad tracks, city streets, or buildings; or locations where the lines or valves may be tampered with.

WASTE OIL AND BALLAST WATER

Sources of Waste Oil

Every depot will sooner or later be confronted with the problem of disposing of waste or off-specification oil. Such material may accumulate from several sources, including water emulsified in the oil, by accident, in the depot; reaction of incompatible oils that have been mixed; foul or wet oil and sludge received from the defueling of ships; oil separated from oily ballast water; sludges or bottom sediment accumulating in the bottoms of storage tanks after a long period of time; oil which has been spilled and then recovered from sumps, harbor basins, or other spaces; and oil contaminated by gasoline.

Disposal of Waste Oil

If a depot has but little of this kind of waste, and it is combustible, it may be burned in a sump, but a practical use for it should be sought. If it will not burn completely, the residuum may be buried or dumped in waste land, or the oil may be used to exterminate mosquitoes, or to lay the dust on roads. Only rarely, if ever, will such material make a good road binder or be a substitute for a regular asphaltic road oil, but it may serve to settle dust.

Treatment of Waste Oil

If the amount of waste oil is large, it may, in many cases, be cleaned and made into a useful fuel by simple treatment even though the resultant oil may not meet Navy specifications for fuel oil. A collected spill of diesel oil probably never would be usable as diesel fuel oil.

As a first step in the treatment of such waste material, free water that will settle is drawn off. This operation may be accomplished either in tanks or sumps. Ordinarily, the next step in treating the residual oil and emulsion is to heat it. Various types of equipment are used.

In many cases simple heating will suffice to remove most of the water from the oil and leave a material that is burnable under the depot boilers or which may be used in other equipment having requirements which are not critical. The oil may not meet specifications—probably will not—but if it can be used locally, no more effort is justified. Oil may often be perfectly burnable in not too exacting equipment (steam atomizing burners) even if it contains a good deal of water in the form of emulsion.

Waste oil may also be treated chemically. As a rule the treatment is controlled on an empirical basis; that is, a sample of the material to be treated is heated and dosed with the proposed chemical reagent before an attempt is made to treat the main batch. Emulsions may also be broken by electrical means and by filtration. Neither process, however, is adaptable to the ordinary needs of a fuel depot.

Special filters are used at depots to clarify diesel fuel oil. These will remove small amounts of emulsion that may be formed in handling the fuel. If a diesel fuel oil appears to be cloudy, it should be cleared up immediately by heating to between 100° and 110° F and allowed to settle. Any free water that settles out should be drawn off.

Avoidance of Emulsion Formation

The quality of the waste oil received by a depot from some sources, such as ship's bunkers, is uncontrollable as far as the depot is concerned, but, by exercising reasonable care the depot can avoid the unnecessary formation of emulsion in its own operation. Moreover, it can sometimes avoid the indiscriminate mixing of waste from several sources, some of which might be readily reclaimable separately but might be made unreclaimable by mixture with the rest. In the first place, wet oil, or oil recovered from spills or sumps should always be kept separate and should not be mixed with clean oil. If free water is churned up with oil, as in passing through a pump or a relief valve, and in particular, a centrifugal pump, the formation of a more or less stable emulsion is rather likely. Transfer of oil containing free water, by centrifugal pumps, is therefore to be avoided.

Certain precautions when defueling will avoid contamination. Soil or clay such as may be contained in oil recovered from spills is apt to act as an emulsifying agent. Such oil, probably containing free water, should not be pumped unnecessarily or agitated. Under no circumstances should oil removed from the ship's bunkers before the ship goes to drydock or repair pier be assumed to be clean and transferred to clean fuel storage without adequate testing. The result may be the contamination of a great deal of clean oil. If there is not time to make sure of the quality of the oil before defueling, at least it may be pumped into an empty tank pending examination. Every effort should be exercised to keep water in any form out of the depot tanks and pipelines and to use separate lines for ballast water and contaminated oils.

Oil Reclamation

Regular oil reclamation plants normally include several tanks which are of steel and suitable for operation to 200° F temperature. Also, there are heaters, pumps for circulation, and some kind of separator for removing most of the oil from the free water before it is discharged into public waters. Oil is received into one or two tanks from which any free water can be removed. The oil is then heated in the steel tanks and further free water drawn off, chemicals being added if necessary. Finally, the clean oil is drawn off to the reclaimed oil tanks and disposed of according to its quality.

If a depot is not equipped with such a plant, facilities may be improvised. Under extreme wartime conditions, one or two of the main storage tanks can be equipped with swing lines and the tanks may then be used for receiving wet oil, permitting preliminary draining of water which is possible after moderate heating. The oil may then be transferred to a steel tank equipped with coils for further treatment at higher temperature.

Disposal of Ballast Water

Tankers pump as much ballast as possible overboard at sea before entering the harbor but if wind and weather are unfavorable, a tanker may arrive at the dock with several thousand barrels of ballast still aboard. Any depot that loads tank ships, therefore, will have to solve the problem of ballast disposal. This problem does not ordinarily arise in loading harbor barges.

Oily ballast water is best received into a tank through a separate line reserved for that purpose. When a reclamation plant is available it is used to receive and treat ballast water. If a depot does not possess an oil reclamation plant nor have a separate tank and separate shore line available, a series of earthen ponds may be used for discharge and settlement. The depot may have a basin separated from public waters by a dike, as when a dredged fill is gradually being built. Such a pond would be a good place to pump ballast after settlement, avoiding any question of pollution of public waters, provided the subsoil is not too permeable. (Advice regarding the design of such facilities is provided by the Bureau of Yards and Docks.) Oil rising to the surface may be reclaimed or burned according to prescribed procedures.

GAGING OPERATIONS

Gaging operations are an integral part of fuel depot operations. This includes the measurement of product in the tank, and depth of water, if any, in the bottom. Also, it is necessary to know the oil temperature and API gravity in order to correct to volume at 60° F. The importance of accurate, correct gaging cannot be over-emphasized. It is only on the basis of accurate gaging that the fuel officer can maintain correct information on his receipts, amount of product in storage, and amount of issues. (Refer to Chapter 6, Measuring and Sampling Petroleum Products for a more detailed discussion of gaging operations.)

APPENDIX I

GLOSSARY

Absolute Viscosity: The force required to move a plane surface of one square centimeter over another plane surface at the rate of one centimeter per second when the two surfaces are separated by a layer of liquid one centimeter in thickness.

Absorption: The physical assimilation of one or more components of a gaseous or vapor phase into a second phase (liquid or solid), the equilibrium distribution of absorbed material in absorbent tending toward homogeneity, as contrasted to the surface phenomena of adsorption.

Absorption Oil: An oil with a high solvent power for light hydrocarbons which are present in natural or refinery gas.

Absorption Plant: A plant for recovering the condensable portion of natural or plant gas, by absorbing these hydrocarbons in an absorption oil (often under pressure), followed by separation and fractionation of the absorbed material.

Acid: The term as used in connection with petroleum usually means sulfuric acid (H_2SO_4) and its aqueous solutions.

Acidity: The amount of free acid in any substance. In lubricating oils, acidity denotes the presence of acid-type constituents whose concentration is usually defined in terms of neutralization number.

Acidizing: A method used to increase production from an oil well. Hydrochloric acid is pumped outward from the well bore into the surrounding formation to dissolve limestone or sandstone, thus making larger flow channels.

Acid Treating: A process for removing undesirable constituents of oil by contacting with sulfuric acid. The acid sludge which is formed by the action of the acid on the oil is separated from the oil and takes with it coloring matter, some sulfuric compounds, and unstable bodies, leaving the oil, after finishing by neutralizing, rerunning, or clay treating, lighter colored and a more stable product than before (if not treated too far).

Additives: Chemicals which are added in minor proportion to a parent substance to create, enhance, or suppress a certain property or properties in the parent material.

Additive-type Oil: A lubricating oil to which chemical agents have been added in the refining process to make it particularly suitable for its intended use.

Adsorption: The adhesion of molecules of gases or liquids to the surface of other bodies, usually solids, resulting in a relatively high concentration of the gas or solution at the point of contact.

Alkali: Any substance such as ammonia, hydrated lime, or caustic soda containing a reactive oxide, which forms salts when reacted with acids. In chemical circles it is often spoken of as a base.

Alkaline: Having the properties of an alkali.

Alkalinity: The amount of free alkali in any substance.

Alkyl Radical: Any radical of the saturated paraffinic series, such as methyl (CH_3); ethyl (C_2H_5); propyl (C_3H_7); etc., having the general formula $C_nH_{2n} + 1$.

Alkaylate: Product obtained in the alkylation process. Chemically, it is a complex molecule of the paraffinic series, formed by the introduction of an alkyl radical into an organic compound.

Alkylation: An important synthetic process for the manufacture of components for aviation gasoline.

Aluminum Base Grease: A grease composed of a mineral oil thickened with aluminum soaps.

Anhydrous: Destitute of water, especially water of crystallization.

Aniline Point: The minimum temperature at which equal volumes of dry, freshly distilled aniline and petroleum products are completely miscible.

Anticline: Folds of earth layers which are bent in such a fashion that they are convex upward.

Antiknock: Resistance to detonation or "pinging" in spark-ignited engines.

Antiknock Agents: Chemical compounds which, when added in small amounts to the fuel charge of an internal-combustion engine, have the property of suppressing or at least of strongly depressing knocking. The principal antiknock agent which has been developed for use in fuels is tetraethyl lead.

Antioxidants: Chemicals added to gasoline, lubricating oils, waxes, and other products to inhibit oxidation.

API: The initials of the American Petroleum Institute.

API Gravity: Arbitrary scale for measuring the density of oils, adopted by the American Petroleum Institute.

Its relation to specific gravity is expressed as follows:

$$\text{Degrees API} = \frac{141.5}{\text{sp. gr. at } 60^\circ/60^\circ\ \text{F}} - 131.5$$

$$\text{sp. gr. at } 60^\circ/60^\circ\ \text{F} = \frac{141.5}{131.5 + \text{degrees API}}$$

Aromatic Hydrocarbons: Hydrocarbons derived from or characterized by the presence of the benzene ring. Many of this large class of cyclic and polycyclic organic compounds are odorous.

Aromatization: Rearrangement of saturated or unsaturated straight-chain hydrocarbons (provided they contain the necessary number of carbon atoms) into ring structures, with subsequent dehydrogenation to form aromatic hydrocarbons of excellent antiknock characteristics or dehydrogenation of naphthenes to form aromatics.

Ash: Inorganic residue remaining after ignition of combustible substances, determined by definite prescribed methods.

Ash Content: An expression of the inorganic matter in a combustible material. It is determined by completely burning the substance and weighing the residue.

Asphalt: Brown to black solid or semisolid bituminous substance occurring in nature or obtained as a residue from cracked stocks or from the distillation of certain crude petroleums. It consists chiefly of a mixture of comparatively nonvolatile hydrocarbons and their derivatives (e. g. sulfur compounds), but usually contains some mineral matter.

ASTM: The initials of the American Society for Testing and Materials.

ASTM Distillation: A distillation test made on such products as gasoline and kerosine to determine the initial and final boiling points and the boiling range.

Atmosphere: The mass of air surrounding the earth. The pressure of the air at sea level is used as a unit of measure.

Atmospheric Pressure: The pressure of air exerted equally in all directions. The standard pressure is that at sea level under which a mercury barometer stands at 760 mm equal to 14.7 lbs./sq. in.

Average Samples: A sample so taken as to contain parts from all sections of a container or pipe, in proportion to the volume of each part.

Ballast: Water, usually salt water, carried in tanker cargo tanks when free of petroleum products in order to reduce buoyancy and improve stability and sea-keeping qualities. Ballast may be clean or dirty, depending on whether it is contaminated with petroleum products.

Barrel: Petroleum industry uses 42 gallon barrel as the standard barrel.

Baume Gravity: Specific gravity expressed on the Baumé scale for liquids lighter or heavier than water. However, the API scale is now used for liquids by the petroleum industry instead of the Baumé scale. Both scales are identical for liquids as dense as water, but for very light oils, there is a difference.

B/D: Abbreviation for barrels per day.

Benzene (Benzol): A hydrocarbon of the composition C_6H_6 and the initial member of the aromatic or benzene series. Its molecular structure is conceived as a ring of six carbon atoms with double linkage between each alternating pair and with hydrogen attached to each carbon atom.

Benzene Ring: A six-membered ring of carbon atoms, joined together by alternate single and double bonds, present in all aromatics.

Benzine: A colorless, flammable, and volatile liquid obtained from petroleum by fractional distillation and consisting of various hydrocarbons. The term has been applied to various petroleum distillates lighter than kerosine, especially when these are used as solvents. It is totally distinct from the aromatic hydrocarbon benzene. ASTM states that this term is archaic and misleading and should not be used.

Benzol: See benzene.

Black Cargoes (Dirty Cargoes): A general term used to describe liquid cargoes of crude oil, diesel fuel, or fuel oils.

Black Oil: A general term applied to crude oil and the heavier and the darker colored petroleum products such as residual fuel oils.

Blended Fuel Oil: A fuel oil which is a mixture of residual and distillate fuel oils.

Blow-By: In internal combustion engines, leakage of combustion gases from combustion chamber, past the rings, into the crankcase.

Boiler Fuel Oil: A fuel oil which is burned in the furnaces of boilers to generate heat.

Boiling Point: The temperature at which the vapor pressure of a liquid is equal to the pressure of the atmosphere. The temperature varies with the atmospheric pressure.

Bomb: Steel cylinder with screwed-on head used as testing device for conducting oil tests under high pressure. Used for test methods such as Reid Vapor Pressure and gum in gasoline.

Booster Stations (Pumping Stations): Suitable storage tanks, motive power, and pumps for pumping oil through pipe lines.

Bottoms: In a distilling operation, that portion of the charge remaining in the still or flask at the end of the run; in pipe stilling or distillation, the portion which does not vaporize.

Bottom Sediment and Water (B S & W): A test made on fuel oils, crude oils, and used crankcase oils to show the approximate amount of sediment and water.

Breathing: The movement of gas (oil vapors or air) in and out of the vent lines of storage tanks due to alternate heating and cooling.

Bright Stocks: Pressure distillate bottoms which have had petrolatum wax removed and which have been filtered so that the stock has a low cold test and a good color (dark red by transmitted light and green by reflected light). Bright stock constitutes the body of lubricants manufactured for internal combustion engines.

B S & W: Abbreviation for bottom sediment and water.

Btu: Abbreviation for British Thermal Unit, a unit of heat commonly used in heat engineering. It is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.

Bubble-Cap Tower: A fractionating tower so constructed that rising vapors pass through layers of condensate on a series of plates. The vapor passes from one plate to the next above by bubbling under one or more caps and out through the liquid on the plate. In bubbling through the liquid the less volatile portions of vapor condense on the plate and overflow to the next lower plate and ultimately back into the reboiler. Fractionation is thereby effected.

Bunker: n. A compartment below deck for storing fuel used in the boiler-firing of a ship; v. i. to load fuel into a vessel's bunker for its own use as distinguished from loading it as cargo.

Bunker "C": An obsolete term used to describe a commercial fuel similar to Navy Heavy.

Bunkering Fuel: Fuel used in the boiler-firing of ships.

Burner Fuel Oil: A fuel oil which is used primarily in oil-burning equipment for the generation of heat in furnaces for heating buildings.

Butadiene: A hydrocarbon (diolefin) used to make synethtic rubber.

Butterworth: A commercially developed method of cleaning and gas-freeing tanker cargo tanks with hot water sprayed from a special machine.

Cable Tool Drilling: A method of drilling in which a steel bit is alternately raised and lowered to strike the formation.

Calcium Base Grease: A grease composed of a mineral oil thickened with calcium (lime) soaps.

Carbon Black: A substantially pure form of finely divided carbon produced from gaseous hydrocarbons by controlled combustion with restricted air supply (furnace black) or by impingement of over-ventilated small flames on iron surfaces (channel black). It is used as a filler in the rubber industry being especially valuable by virtue of the improved wearing quality which it imparts to tires. Smaller quantities are used as pigment in printing inks and paints.

Carbon Residue: The residue remaining after volatilizing an oil under specified conditions.

Casinghead: A fitting at the top of the casing (or outer pipe) of an oil or gas well, which permits cleaning, pumping, and the separation of oil or gas.

Casinghead Gasoline (Natural Gasoline): Gasoline recovered from the gas issuing from the casinghead of oil wells and the gas from natural gas wells.

Catalyst: A substance which effects, provokes, or accelerates reactions without itself being altered.

Catalytic Cracking: A method of cracking in which a catalyst is employed to bring about the desired chemical reaction.

Caustic: An aqueous solution of sodium hydroxide (lye) used for the neutralization of oils following acid treatment.

Centipoise: 0.01 poise or centistokes times specific gravity at a test temperature.

Centistokes: 0.01 stoke.

Centrifugal Separator: A machine utilizing centrifugal force to separate two phases of differing gravity—such as wax from oil or acid sludge from treated oil.

Centrifuge: An instrument for separating liquids of different specific gravities by use of centrifugal force.

Cetane: A saturated liquid hydrocarbon used as the primary reference fuel when determining the ignition characteristics of diesel fuels.

Cetane Number: Diesel fuel ignitability performance measured by the delay of combustion after injection of the fuel. It represents a comparison of a fuel with standards which are cetane in alpha-methyl-naphthalene.

Christmas Tree: An assembly of pipes and valves, at the top of the casing of an oil well, which controls the flow of oil from the well.

Chromometer: An instrument used for determining the color of gasolines, kerosines, and white oils.

Clean Cargoes: Cargoes such as aviation and motor gasolines, diesel oils, jet fuels, kerosines, and lubricating oils.

Cloud Point: The temperature at which paraffin wax or other solid substances begin to crystallize out or separate from solution when an oil is chilled under prescribed conditions.)

Cohesive: When referring to grease or oil, good cohesive properties mean that the various particles of the lubricant hold tightly together and resist being pulled apart by mechanical action such as occurs in gears and bearings.

Coke: The carbon residue left in the stilll after a charge of reduced crude oil has been run to dryness. Coke is largely carbon and is used mostly as a domestic fuel, but has some sale for special purposes, such as carbon electrodes.

Coking: The process of distilling a charge of oil to coke. In the last part of a coking run on a shell still, the bottom of the still is at a red heat and most of the volatile matter is driven out, leaving the coke hard and dry.

Cold Pressing: The process of separating wax from oil by chilling and filtering under pressure.

Cold Settling: A process used for the removal of petrolatum wax from cylinder stock and high viscosity distillates. A naphtha solution of the oil is chilled and the wax crystallizes out. It is then allowed to stand until the wax settles to the bottom leaving a clear, nearly wax-free oil-naphtha mixture at the top which is stripped of naphtha, after percolation through clay, to produce bright stock.

Colorimeter: An apparatus used to determine the color of petroleum products.

Combustible: The general term describing any material that will burn. However, in the case of petroleum products only those which give off flammable vapors above 80° F are classed as combustible.

Combustion: The act or process of burning. Chemically, it is the process of rapid oxidation caused by the union of the oxygen of the air, which is the supporter of combustion, with any material that is capable of oxidation.

Commingling: The admixture of two or more petroleum products resulting from improper handling, particularly in pipe line or tanker operations.

Composite Sample: A sample which is a mixture of samples taken from the upper, middle, and lower thirds of a container.

Compound: A substance formed by the union of two or more chemical elements in definite proportions by weight.

Compound Oil: A mineral oil to which animal or vegetable fat has been added. (Later usage has included the addition of other additives.)

Compounding: The dissolving of animal or vegetable fats or waxes such as sperm oil in petroleum oils in order to impart special properties. For example, steam cylinder oils usually contain 5 percent to 10 percent animal fat in order to make them emulsify readily with water and maintain a lubricating film on wet cylinder walls of a steam operated compressor.

Condensate: The liquid product coming from a condenser.

Conradson Test: A carbon residue test method for determining the amount of carbon deposited after oil has burned. In this method, a sample of oil is tested by driving off volatile portions, weighing the residue, and calculating the percentage of original oil.

Consistency: A measure of the solidity or fluidity of semi-solid products such as grease, petrolatum, and asphalt.

Contamination: The addition to a petroleum product of some material not normally present as dirt, rust, water, or another petroleum product.

Corrosion: Detrimental change in the size or characteristics of material under conditions of exposure or use. It usually results from chemical action either regularly and slowly as in rusting, or rapidly as in metal picking.

Cracking: Breaking down an organic compound with a high molecular weight to form compounds of smaller molecular weight.

Crude Petroleum: A naturally occurring mixture, consisting predominantly of hydrocarbons, and/or of sulfur, nitrogen and/or oxygen derivatives of hydrocarbons, which is removed from the earth in liquid state or is capable of being so removed. Crude petroleum is commonly accompanied by varying quantities of extraneous substances such as water, inorganic matter, and gas.

Cup Grease: Originally used to indicate a grease for use in compression cups, but usage now indicates a grease having a calcium fatty acid soap base.

Cut: Same as fraction.

Cut-Back: To reduce the viscosity of a heavy product by adding and blending a lighter product with it.

Cutting Oil: Oil used to lubricate and cool metal cutting tools. It may be water-soluble or water-insoluble. Usually mineral oils are blended with lard oil or other oiliness or extreme pressure agents to produce water-insoluble cutting oils, or with sulfonated products and other emulsifying agents to produce soluble cutting oils.

Cycilization: Rearrangement of saturated or unsaturated straight-chain hydrocarbons into a cyclic structure.

Cylinder Oils: Oils used to lubricate the cylinders and valves of steam engines.

Cylinder Stock: A class of highly viscous oils so called because originally their main use was in the preparation of products to be used for steam cylinder lubrication. Cylinder stocks are usually produced as bottom oils but may also be distilled under suitable conditions. They may be high or low cold test according to whether they have been cold settled or not.

Deasphalting: A process for removing asphalt from reduced crude which utilizes the widely different solubilities of nonasphaltic hydrocarbons and asphaltic compounds in liquid propane.

Dehydrogenation: The process of removing hydrogen from adjacent carbon atoms of an organic compound with resultant formation of a double bond.

Demulsibility: The ability of an oil to separate from any water with which it is mixed.

Density: The mass of a unit volume. Its numerical expression varies with the units selected.

Detergents: Compounds (typically aralkyl sulfonates, fatty alcohol sulfates etc.) which act to wet, disperse, and deflocculate solid particles. The respective functions, in turn, are assumed to be dependent upon surface tension, interfacial tension, viscosity, and perhaps even sudsing of the solution. (See synthetic detergents.)

Detergent Oil: A lubricating oil possessing special sludge-dispersing properties for use in internal combustion engines. These properties are usually conferred on the oil by the incorporation of special additives. A detergent oil has the ability to hold sludge particles in suspension and thus to promote engine cleanliness.

Deterioration: Any undesirable chemical or physical change which takes place in petroleum products while in storage or in use.

Detonation: Sharp explosion. The term is applied to the knock-producing type of combustion in spark ignition internal combustion engines which may be induced by low octane rating of fuel, high air/fuel ratio, advanced spark, or excessive engine or mixture temperature.

Dewaxing: Removal of wax. In one method, propane is used as a refrigerant and wax antisolvent for removing wax from wax-bearing distillates.

Dielectric Strength: The rating of the insulating power of insulating oils. Thus, oils with the highest dielectric strength (expressed in kilovolts) are the best electrical insulators.

Diesel Index: The product of aniline point in degrees Fahrenheit and the API gravity at 60° F divided by 100. The diesel index increases with the increase in cetane number.

Dilution of Crankcase Oils: The percentage of fuel in used internal combustion engine oil.

Diolefins: Open-chain hydrocarbons having two double bonds per molecule.

Dirty Cargoes: See black cargoes.

Distillate: That portion of oil which is removed as a vapor and condensed during a distillation process.

Distillate Fuel Oils: Fuel oils which are distillates derived directly or indirectly from crude petroleum (chiefly from the gas oil fraction).

Distillation: Distillation generally refers to vaporization processes in which the vapor evolved is recovered, usually by condensation, and a separation effected between those fractions which vaporize and those which remain in the bottoms. (See fractional distillations.)

Distillation Range: Initial boiling point, final boiling point, and temperatures at which various fractions are distilled, as determined under specified test conditions.

Doctor Test: A qualitative method of detecting undesirable sulfur compounds in petroleum distillates, that is determining whether an oil is sour or sweet.

Downgrading: Assigning a petroleum product for use where a lower grade of product would normally be employed, provided it meets the requirements for the lower grade.

Draw Works: The hoisting equipment on a rotary drilling rig, used to lift and lower the pipe into the hole.

Dropping Point of Grease: The temperature at which grease passes from semisolid to liquid state under specified test conditions.

Drying Oil: An oil which possesses the property of readily absorbing oxygen from the air and of changing to a relatively hard, tough, and elastic film when exposed in thin layers to the atmosphere.

Emulsibility: The ability of an oil to mix readily with water. Oils of good emulsibility make emulsions readily with water.

Emulsifying Agents: Surface-active substances which help to promote an emulsion and to keep it stable after formation.

Emulsion: Intimate mixture of two immiscible liquids, one of them being dispersed in the other in the form of fine droplets.

End Point (Final Boiling Point): The highest temperature indicated on the thermometer inserted in the flask during a standard laboratory distillation test. This is generally the temperature at which no more vapor can be driven over into the condensing apparatus.

E P Lubricant: Extreme pressure lubricant.

Ester: A compound formed by the action of an alcohol and an acid.

Evaporation Loss: The loss of petroleum products—particularly gasoline—through the evaporation of the most volatile fractions.

Existent Gum: Under specified test conditions, the amount of nonvolatile residue (expressed as milligrams per 100 milliliters of sample) present in gasoline as received for the test.

Explosive Limits (Explosive range): The limits of percentage composition of mixtures of gases and air within which an explosion takes place when the mixture is ignited.

Extreme Pressure Lubricant: Lubricating oil or grease which contains a substance or substances specifically introduced to prevent metal-to-metal contact in the operation of highly loaded gears.

Fat: A naturally occurring mixture of triglycerides.

Fatty Oil: A fat which is liquid at room temperature.

Fault: Geologically, a structural closure caused by the fracturing of the crustal rocks during each movements.

Fillers: Any substance such as talc, mica, or various powders, which may be added to greases to make them heavier in weight or in consistency, but which form no useful function in making the grease a better lubricant.

Film Strength: The ability of a lubricant to form a film, which separates bearing surfaces, without breaking down and causing metal-to-metal contact. (The higher the film strength, the greater the load the lubricant can carry.)

Final Boiling Point: See end point.

Fire Point: The lowest temperature at which, under specified test conditions, a petroleum product vaporizes sufficiently rapidly to form above its surface an air-vapor mixture which burns continuously when ignited by a small flame.

Flammable: Term describing any combustible material which can be ignited easily and which will burn rapidly. Petroleum products which have a flash point of 80° F or lower are classed as flammable.

Flash Point: The lowest temperature at which, under specified test conditions, a petroleum product vaporizes rapidly enough to form above its surface an air-vapor mixture which gives a flash or slight explosion when ignited by a small flame.

Flushing Oil: Oil or a compound designed for the purpose of removing used oil, decomposition products, and dirt from lubrication passages, crankcase surfaces, and moving parts of automotive engines accessible to the lubrication system.

Fraction: A portion of distillate (having a particular boiling range) separated from other portions in the fractional distillation of petroleum products.

Fractional Distillation (See distillation): Fractional distillation implies the use of equipment for effecting a more complete separation between the low and high boiling components in a mixture being distilled than does the general term distillation. It is usually accomplished by the use of a bubble tower or its equivalent.

Fractionation: As used in petroleum, generally means fractional distillation.

Freeboard: The distance measured vertically downward at the side of a vessel, amidships, from the upper edge of the deck line to the upper edge of the load line.

Freezing Point: The temperature at which a substance freezes.

Fuel Depot (Storage terminal, tank farm): Bulk storage installation composed of storage tanks and related facilities such as docks, loading racks, and pumping units.

Fuel Oil: Any liquid petroleum product used for the generation of heat in a furnace or firebox.

Fuller's Earth: Any of a class of naturally-occurring absorbent clays, so called from their original use in fulling cloth, but now used more extensively as a filter medium for refining oils, fats, etc.

Furnace Oil: A distillate fuel intended primarily for domestic heating.

Gas Absorption: See absorption.

Gas Indicator (Combustible gas indicator): An instrument used to detect the presence of flammable gases or vapors in the atmosphere. (Also known by various trade names as explosimeter, vapotester, etc.)

Gas Oil: Term originally used to mean oil suitable for cracking to make illuminating gas. Now used to designate an overhead product, intermediate between refined oils and low viscosity lubricating oils, used primarily as thermal or catalytic cracking feed stock, diesel fuel, furnace oil, and the like.

Gasoline: A volatile liquid hydrocarbon fuel generally made from petroleum.

Go-Devil: A scraping device which is forced through pipe lines to ensure that there are no obstructions.

Gravity: See API gravity.

Grease: A combination of a petroleum product and a soap, or a mixture of soaps, suitable for certain types of lubrication.

Gum: Resin-like, naphtha-insoluble deposits formed by the oxidation and polymerization of certain petroleum products, particularly gasoline.

Heavy Ends: A term used in speaking of oils where the distillation range is of importance, meaning the highest boiling portion present. The maximum or end point as obtained in the 100 milliliter distillation of a sample of gasoline is determined largely by the amount and character of the heavy ends present in the gasoline.

Heavy Duty Oils: Lubricating oils which were originally developed for use in certain types of high-speed diesel engines and spark ignition engines subject to high piston and crankcase temperatures. They combine the properties of detergency, resistance to oxidation, and relative freedom from corrosive action on alloy-type bearings. Normally they contain special additives which confer these properties.

Hydraulic Fluid: Fluids which may be of petroleum or nonpetroleum origin intended for use in hydraulic systems. Low viscosity, low rate of change of viscosity with temperature, and low pour point are desirable characteristics.

Hydrocarbon: Any of the compounds made up exclusively of hydrogen and carbon in various ratios.

Hydroforming: A special catalytic reforming process employed for upgrading straight-run gasolines.

Hydrofrac: In oil well drilling, a method developed to create highly permeable flow channels through the formation, radiating out from the well bore.

Hydrogenation: The process of adding hydrogen to the hydrocarbon molecule.

Hydrometer: An instrument for determining the specific gravity of a liquid.

Hydrostatic Head: That portion of existing pressure at a point which is attributable to the weight of the superimposed column of fluid.

Hydrous: Containing water chemically combined, as in hydrates or hydroxide.

Hydroxide: A compound consisting of an element and the radical or ion, OH, as sodium hydroxide (NaOH).

Ignition Quality: The ability of a fuel to ignite upon injection into the cylinder.

Illuminating Oil: A petroleum product, heavier than gasoline, used for lighting purposes.

Inflammable: Same as flammable, but flammable is the preferred term.

Inhibitors: Chemical compounds which, when added in small amounts, reduce rates of chemical reactions.

Initial Boiling Point: The temperature at which the first drop of distillate falls from the condenser into the receiver in a standard laboratory distillation procedure.

Innage: Depth of liquid in a tank, measured from the surface of the liquid to the tank bottom.

Inorganic Acid: An acid of nonorganic origin, hence containing no carbon.

Inorganic Compound: A compound containing no carbon, hence composed of matter other than animal or vegetable, such as clay or glass.

Insoluble: Incapable of being dissolved in a liquid.

Insoluble Oils: Oils which do not form stable emulsions or colloidal solutions with water.

Insulating Oils: Oil, such as transformer oil, used to insulate and cool the core and windings of transformers.

Isomerization: Process for altering the fundamental arrangement of the atoms in a molecule without adding or removing anything from the original materials. In petroleum refining, straight-chain hydrocarbons are converted to branched-chain hydrocarbons of substantially higher octane rating, in the presence of a catalyst, usually at moderate temperature and pressures.

Iso-Octane: A hydrocarbon showing 100 octane value, used primarily as a reference fuel in determining the octane rating of gasolines. It is isomeric with normal octane, and therefore has the same chemical formula, (C_8H_{18}).

Isopentane: A saturated branched-chain hydrocarbon having 5 carbon atoms and 12 hydrogen atoms, obtained by fractionation of natural gasoline or isomerization of normal pentane. It is used extensively as a component of aviation gasoline.

Journal: The part of a shaft or axle which rotates in or against a bearing.

Kerosine: A general term covering the class of refined oils boiling between 370° F and 515° F, used primarily in domestic oil lamps and cooling stoves.

Kinematic Viscosity: The ratio of viscosity of a liquid to its specific gravity at the temperature at which the viscosity is measured.

Knock: In gasoline engines, detonation caused by sudden burning of the last remaining portion of the fuel in the combustion chamber.

Knock Characteristics: Tendency of a gasoline to knock. (See octane number and performance number.)

Lacquer (Varnish): A coating similar to a natural varnish, left on engine parts as a result of high temperature of oil and gasoline.

Lampblack: A solid product, consisting largely of carbon, obtained by the incomplete combustion of hydrocarbon materials. It is substantially different from carbon black and channel black, being greyish in color.

Lard Oils: Animal oils prepared from chilled lard or from the fat of swine. They are compounded with mineral oils to yield lubricants of special properties.

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Lead Susceptibility: The ability of gasoline to respond to the addition of tetraethyl lead, as reflected in the increase in octane number per increment of lead added.

Light Ends: In any given batch of oil, that portion of lowest boiling point. In gasoline, it is the portion distilling off up to about 158° F. In making lubricating oils, the light ends must be removed in order to produce finished oils of high flash point.

Liquefied Petroleum Gas: Gaseous forms of petroleum which have been converted into liquids by changes in temperature and pressure.

Liquid Fuel: Any liquid used as fuel which can be poured or pumped.

Lithium Base Grease: A grease composed of a mineral oil thickened with lithium soaps.

Load Line: The line on a vessel defining the maximum mean draft to which the vessel may lawfully be submerged.

Lower Toxic Limit: The maximum permissible content of petroleum vapor (0.1 percent by volume) in a tank or compartment which is to be entered by persons.

LPG: Abbreviation for liquefied petroleum gas.

Lubricant: Material, especially oils, greases, and solids such as graphite, used to decrease friction.

Lubricating Grease: A solid or semisolid material consisting of fluid lubricant(s) and soap and/or thickening agent(s), with or without additives or fillers, suitable for reducing friction between mechanical moving parts.

Medicinal Oil: A highly refined, colorless, tasteless, and odorless petroleum lubricating oil of low viscosity used as a medicine in the nature of an internal lubricant.

Mercaptans: Organic compounds having the general formula R-SH, meaning that the thiol group (SH) is attached to a radical such as CH_3 or C_2H_5. The simpler mercaptans have a strong, replusive, garlic-like odor which becomes less pronounced with increasing molecular weight and higher boiling points.

Metal Deactivators: Organic compounds which suppress the catalytic action of heavy metal compounds sometimes contained in hydrocarbon distillates. (Metal compounds tend to promote the formation of gum.)

Mid Continent Oils: Petroleum oils obtained from the central regions of the United States, usually having characteristics between those of Pennsylvania and Coastal oils.

Mill Scale: A magnetic product formed on iron and some steel surfaces during the manufacturing process.

Mineral Oil: A wide range of products derived from petroleum and within the viscosity ranges of products spoken of as oils.

Mineral Seal Oil: A light lubricating oil which is chemically refined.

Mixed-Base Grease: A grease composed of a mineral oil thickened by soaps made from two alkalis.

Mixture: The combination of two or more substances united in such a way that each retains its original properties.

Napalm: Gasoline which has been chemically thickened so that it spreads over the ground while burning instead of going up instantaneously.

Naphthas: Oils of low boiling range (80° F to 440° F), usually of good color and odor when finished. Sometimes refers to gasoline components and sometimes to special products, solvents, etc.

Naphthalene: A hydrocarbon (polynuclear aromatic) which forms plate-like crystals, has the odor of moth balls, and is always present to a considerable extent in coal tar and coal gas.

Naphthenes: Saturated hydrocarbon series, characterized by the closed-chain arrangement of carbon atoms.

Napththenic Crudes: Crude oils containing large proportions of naphthenic compounds.

Natural Gasoline: See casinghead gasoline.

Neutralization Number: The number of milligrams of potassium hydroxide (an alkali) required to neutralize one gram of a sample.

Neutral Oils: Term used quite generally to mean a lubricating oil of medium viscosity made from a wax-bearing crude.

Nonsparking Tools: Tools made of a metal alloy which, when struck against other objects will not usually cause sparks of sufficient temperature to ignite flammable vapors.

Nonviscous Neutrals: The lighter weight oils distilled overhead and used for manufacture of oils for extremely light lubricating purposes.

Octane: The eighth member of the paraffin or saturated series of hydrocarbons, having a boiling point of 258° F, and the chemical formula C_8H_{18}.

Octane Number: Term used to indicate numerically the relative antiknock value of automotive gasolines, and of aviation gasolines having a rating below 100. It is based on a comparison with the reference fuels, iso-octane (100 octane number) and normal heptane (0 octane number). The octane number of an unknown fuel is the volume percent of iso-octane with normal heptane which matches the unknown fuel in knocking tendencies under a specified set of conditions. Either the Motor Method or the Research Method may be used in determining octane rating of automotive gasolines; either the Aviation Method or Supercharge Method may be used in determining the octane rating of aviation gasolines. The test method employed must be reported with the octane rating. (See Performance Number.)

Octane Number, Aviation Method: Octane number of aviation gasolines, determined by a method of test which indicates the knock characteristics at a lean fuel-air ratio (lean or cruise rating).

Octane Number, Cruise Rating: See Octane Number, Aviation Method.

Octane Number, Lean Rating: See Octane Number, Aviation Method.

Octane Number, Motor Method: Octane number of automotive gasolines, determined by a method of test which indicates the knock characteristics under severe conditions (high temperatures and speed).

Octane Number, Research Method: Octane number of automotive gasolines, determined by a method of test which indicates the knock characteristics under mild conditions (temperatures and speed approximating ordinary driving conditions).

Octane Number, Supercharge Method: Octane number of aviation gasoline, determined by a method of test which indicates the knock characteristics under super-charge rich-mixture conditions.

Off Specification: Term describing a product which fails to meet the requirements of the applicable specification.

Oiliness: Under certain conditions of lubrication, one lubricant may reduce the friction in a bearing more than a similar oil of the same viscosity and applied in the same way. The oil that reduces friction the most is oilier and is said to have a higher degree of oiliness.

Olefin: Any open-chain hydrocarbon having one or more double bonds per molecule.

On Stream: When a refinery processing unit is in operation.

Organic: Pertaining to compounds produced in plants and animals or carbon compounds of artificial origin.

Outage: See ullage.

Overhead: In a distilling operation, that portion of the charge which is vaporized, led off through suitable lines and condensed to liquid in cooling coils, thus separating it from the portion of the charge withdrawn from the condenser as gas or vapor.

Oxidation: In general, the process in which oxygen is added to a compound. The oxidation reaction in petroleum may lead to gum or resin formation which is of importance in the utilization of gasolines, particularly those that contain unsaturated compounds.

Oxidation Inhibitors: Chemical compounds added to petroleum products in small quantities to reduce the rate of oxidation.

Pale Oil: Lubricating oils of light color (not darker than about 4 NPA) and of comparatively low viscosity, usually obtained as overhead products.

Paraffin-Base: Products prepared from paraffin-type crude oils. Lubricating oils made from these crudes are normally distinguished from similar oils made from other crudes (both oils equally well refined) by higher gravity, better resistance to deterioriation in service, and higher viscosity index.

Paraffin Wax: The wax removed by chilling and pressing paraffin distillates from wax-bearing crudes such as Mid Continent and Pennsylvania crudes. It is an overhead product. Paraffin wax has a very definite crystalline structure and the crystals are much larger than those obtained from petroleum wax.

Penetration Number: The depth, in tenths of a millimeter, that a standard cone penetrates a sample of grease under prescribed conditions. (See Unworked Penetration, Worked Penetration.)

Penetrometer: Apparatus for measuring penetration of grease.

Pensky Martens: A closed cup test method for determining flash and fire point of oils.

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Performance Number: An arbitrary scale, normally used to denote knock characteristics of aviation gasolines having an octane rating above 100. The reference fuel is isooctane with additions of tetraethyl lead. Both lean and rich-mixture ratings are reported. (See octane number.)

Permeability: A measure of the ease with which a fluid can flow through a porous medium. The easier the flow, the greater the permeability of the medium.

Petrochemicals: Organic chemicals manufactured from petroleum.

Petrol: Term used, particularly in England, to designate petroleum or its derivatives.

Petrolatum Wax: A high boiling wax product obtained from cylinder stocks by the cold settling process. To the human eye, the wax appears to be amorphous, but under the microscope is seen to consist of a network of needle crystals. Petrolatum wax, as obtained from the cylinder stock, has a reddish brown color similar to that of the oil but by further refining may be produced in any shade up to pure white. Petrolatum wax is seldom sold as such, but is mixed with oils of proper color to make commercial petrolatums.

Petroleum: A compound consisting of a mixture of hydrocarbons.

Plasticizer: A compound added to a lacquer to counteract the tendency of the finished surface to become brittle.

Platforming: A special reforming process, employing platinum as a catalyst, for upgrading straight-run gasolines.

Plimsoll Mark: Load line mark (British).

Poise: Unit of absolute viscosity.

POL: A broad term which includes all petroleum products used by the Armed Forces. It originated as an abbreviation for petrol, oil, and lubricants.

Polymerization: A process for uniting light olefins to form hydrocarbons of higher molecular weight.

Potential Gum: Gum which may be formed and deposited by a gasoline during storage or under accelerated aging conditions.

Pour Point: The lowest temperature at which an oil will pour or flow when chilled without disturbance under specified conditions. By ASTM instruction, it is taken as the temperature 5° F above the solid point.

Pour Point Depressant: A compound which, when added to a wax-containing product (a diesel fuel, lubricant etc.) reduces the solid point of the product. The additive apparently functions by modifying the crystal structure of wax which separates at low temperatures.

Precipitate: Material, formed during the accelerated oxidation of loaded fuel, which is insoluble in both the fuel and the gum solvent.

Precipitation Number: The number of milliliters of solid matter precipitated in a mixture of oil and solvent under prescribed conditions.

Pressure Distillate: The light, gasoline-bearing distillate product from the pressure stills which has been produced by cracking, as contrasted with virgin or straight-run stock.

Pressure Distillate Bottoms: Residue from distillation of topped crude.

Production: Raising crude oil from underground geological formations to the earth's surface.

PSI: Abbreviation for pounds per square inch.

Pumping Stations: See booster stations.

Qualified Petroleum Products: Products which have passed successfully certain tests required to determine whether or not they conform to all qualification test requirements of applicable specifications.

Raffinate: Term applied in solvent-refining practice to that portion of the oil which remains undissolved and is not removed by the selective solvent used.

Raw Gasoline: See straight-run gasoline.

Reactivation: The restoration of a used catalyst to a chemically or physically active state.

Reclamation: Procedure required to restore or change the quality of contaminated petroleum products to meet desired specifications.

Red Oils: Lubricating oils of a red color, usually produced as bottom oils in reducing stills.

Reduced Crude: The bottoms remaining from a distillation of crude oil.

Reduction: A distillation where the oil remaining in the still (the bottom) is an important product of the operation, this bottom being concentrated (reduced) to viscosity or other required test by distilling off the lighter portions of the charge.

Reflux: The liquid which flows down a fractionating tower to serve as a cooling and material transfer medium in the fractionation process.

Reforming: A cracking process for converting low octane number naphthas or gasolines into high octane number products.

Regeneration: In catalytic cracking, removal of carbon from the catalyst in order to make it fit for reuse.

Reid Vapor Pressure: The measure of pressure exerted on the interior of a special container (Reid Vapor Pressure apparatus), under specified test conditions, because of the tendency of the product to vaporize.

Reservoir: A geological structure of rocks so formed as to trap oil or gas.

Residual Fuel Oils: Fuel oils which are either topped crude petroleum or viscous cracked residuum.

Residuum: The dark colored, highly viscous oil remaining from crude oil, after the more volatile portion of the charge has been distilled off.

Resin: Originally, any of various solid or semisolid natural organic substances, chiefly of vegetable origin; amorphous; usually yellowish to brown in color; transparent or translucent; soluble in ether, alcohol etc., but not in water; specifically pine resin, or rosin. More recently the term has been used to include synthetic resins, such as Bakelite, built up by chemical reaction, condensation, or polymerization.

Rotary Drilling: Drilling by rotating a drill bit on the end of a string of pipe.

SAE: Initials of Society of Automotive Engineers.

SAE Viscosity: An arbitrary system for classifying motor oils according to their viscosities, established by the Society of Automotive Engineers.

Salt Dome: Geological formation resulting from intrusion of rock salt into overlying sedimentary beds.

Saponification: The process of soap-making which is the result of a chemical reaction of fat or fatty acid and an alkali.

Saponification Number: Number of milligrams of potassium hydroxide required to saponify one gram of compounded oil.

Saturated Hydrocarbons: Hydrocarbons in which all the valency bonds of the carbon atom have been fulfilled.

Saybolt Furol Viscosity: The viscosity of a material as measured on a Saybolt Furol viscosimeter, used primarily for high viscosity materials. The results are approximately one tenth those obtained on a Saybolt Universal viscosimeter.

Saybolt Universal Viscosity: The time in seconds for 60 cc of liquid to flow through the capillary tube in a Saybolt viscosimeter.

Scavenging Agent: A gasoline-soluble bromine compound added with tetraethyl lead in order to prevent the formation and deposition of lead oxide in cylinders.

Scupper Plugs: Plugs of various types, tightly fitted or cemented in all scupper holes on the weather deck of tankers while loading, discharging, or shifting cargo in port. In the case of a spill of oil, the plugs usually prevent harbor pollution by retaining the spill on decks.

Secondary Recovery: In drilling, a method of forcing oil to flow into the well bore after natural forces fail. Water, gas, or air is usually employed.

Sediment and Water: Solids and aqueous solutions which may be present in an oil and which either settle out on standing or may be separated more rapidly by a centrifuge.

Shale: A sedimentary rock, formed by the consolidation of mud or clay.

Shale Oil: Crude oil derived from shale.

Shell Capacity: The amount of oil a tank car or tank truck will hold when the oil just touches the underside of the top of the tank shell.

Shooting: A method of increasing production from an oil well. (Jellied nitroglycerin is used to enlarge the area at the bottom of the hole and to create fractures through the formation, thus increasing the flow of oil.)

Sligh Oxidation Test: A test method for determining oxidation-resistance of various types of oils.

Sludge: Deposits (which may be hard and lumpy, grainy, and/or pasty) in a lubricating system. These deposits, which are insoluble in the oil, may be the result of contamination of the oil, or from deterioration of the oil itself.

Slugging: In airplanes, loss of liquid fuel from tank vents owing to the pulling action of escaping vapors.

Slushing Oil: An oil or grease-like material used as a temporary protective coating against corrosion.

Smoke Test: A test made on kerosine which shows the highest point to which the flame can be turned before it will smoke.

Soap: A compound made by the action of an alkali on a fat or fixed oil.

Soda Base Grease: A grease composed of a mineral oil thickened with sodium soaps.

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Soluble Oils: Oils which readily form stable emulsions or collodial solutions with water. They usually contain metallic or ammonium soaps or sulfonated oils and may be used for cutting oils, detergents, insecticides, etc.

Solvent Extraction: A process for separating compounds of approximately the same boiling points, but of different chemical types by employing solvents in which the solubilities of these compounds are widely different.

Sour Crude: Crude oil containing sufficiently large quantities of sulfur and sulfur compounds as to require chemical treatment for removal. Characterized by objectionable pungent odor.

Specific Gravity: The ratio of the weight of a given volume of the material at 60° F to the weight of an equal volume of distilled water at the same temperature, both weights being corrected for the buoyancy of air.

Split Cargo: See composite cargo.

Stability: Property of product which gives it the ability to retain its physical and chemical properties intact, even during extended storage.

Stabilizer: A fractionating column and heat exchanger system operating under pressure of 200-300 lb. gage, which is used to remove the very volatile light hydrocarbons (propane and lighter) present in raw cracking still distillate, absorption plant naphtha, and casinghead gasoline.

Steam Cylinder Oil: An oil that is used to lubricate the cylinder walls, pistons, and valves of a steam engine.

Steam Emulsion Number: The time in seconds for a given amount of oil to separate from condensed steam under prescribed test conditions.

Still: An apparatus in which a substance is changed by heat, with or without chemical decomposition, into vapor, which vapor is then liquefied in a condenser and collected in another part of the apparatus.

Stock: In general, any oil which is to receive further treatment before going into finished products.

Stoke: The unit of kinematic viscosity.

Straight-Run Gasoline (Raw gasoline): A gasoline which is obtained directly from crude by fractional distillation.

Strapping: Measuring storage tanks and cargo carriers for capacity.

Stratigraphic Trap: A structural formation in which the oil-producing formation pinches out and disappears up the structure, forming an impervious layer of cap rock.

SUS: Initials of Saybolt Universal Seconds. (See Saybolt Universal viscosity.)

Sweet Crude: Crude oil containing so little sulfur as to render unnecessary any chemical treatment for the removal of sulfur or sulfur compound.

Synthetic Detergent (See detergent): The term synthetic is used to distinguish the newer chemical cleansers from the older ones such as soaps.

Synthetic Fuels: Term commonly used to indicate fuels manufactured from sources other than crude petroleum (such as shale or coal).

Tank Farm: See fuel depot.

Tetraethyl Lead: A volatile lead compound, $Pb(C_2H_3)4$, which, when added in small proportions to gasoline, increases the octane rating.

Tetraethyl Lead Susceptibility: See lead susceptibility.

Thermal Cracking: The process of cracking by heat or by heat and pressure.

Thermal Value: Calories per gram or btu per pound produced by burning fuels.

Thief: A sampling apparatus so designed that a liquid sample can be obtained within 1/2 inch of the bottom of a tank.

Thiefing: Taking a sample from the bottom of a tank, primarily to determine the amount of free water present. Also, commonly used to mean measuring the amount of water at the bottom of a tank by means of a tape and bob, or by a gaging pole.

Tolerance: An allowable variation from a specified limit.

Toluene (Toluol): An aromatic hydrocarbon, $C_6H_5CH_3$, the principal component of TNT.

Toluol: See toluene.

Topping: Removal of volatile fractions by distillation.

Topped Crude: Crude oil from which some of the lighter constituents have been removed by distillation.

Transformer Oil: An oil used in transformers to conduct heat, soften and protect the insulation, and reduce oxidation.

Turnaround: That period of time required by a vessel to make one complete round trip between two ports and complete preparations to resume the cycle.

Ullage (Outage): The distance from a given point at the top of a container down to the surface of the liquid.

Unsaturated Hydrocarbon: Hydrocarbon having a deficiency of hydrogen.

Unworked Penetration: The penetration at 77° F of a sample of grease which has received only the minimum handling in transfer from sample can to test apparatus and which has not been subjected to the action of a grease worker.

Valence: The combining capacity of one atom of an element as compared with that of an atom of hydrogen.

Vapor Explosive Range: See explosive limits.

Vaporization: Conversion of a liquid to its vapor, such as the conversion of water into steam.

Vapor Lock: Malfunctioning of carburetor and fuel feed systems of internal combustion engines caused by evolution of bubbles of vapor from the gasoline.

Vapor Pressure: The outward pressure of a mass of vapor at a given temperature when enclosed in a gas-tight vessel. It is an index to the volatility of the liquid from which the vapor was produced.

Varnish: See lacquer.

Viscosity: The property of resisting flow or deformation which all liquids possess.

Viscosity Index: A measure of the temperature coefficient of viscosity of a lubricating oil as expressed by the relationship between its viscosity at 100° F and its viscosity at 210° F.

Viscosimeter: An apparatus for determining viscosity.

Viscous Neutrals: The heavier distillates ordinarily used for blending purposes or in the manufacture of straight lubricants such as turbine oils and light motor oils.

Volatility: A measure of the propensity of a substance to change from the liquid or solid state to the gaseous state. A volatile liquid is one which readily vaporizes at comparatively low temperatures.

Wet Gas: A gas containing a relatively high proportion of readily condensable constituents.

White Oils: Term applied to substantially colorless, tasteless, and odorless oils, covering a wide range of viscosities.

Worked Penetration: The penetration at 77° F of a sample of grease which has been worked or mechanically kneaded prior to transfer to test apparatus.

APPENDIX II

REFERENCE LIST OF PUBLICATIONS

GOVERNMENT PUBLICATIONS

Military Standardization Handbook, Petroleum Operations, MIL-HDBK-201A

Military Standardization Handbook, Quality Surveillance Handbook for Fuels and Lubricants, MIL-HDBK-200B

Military Standardization Handbook, Conversion Factors and Logistics Data for Petroleum Planning, MIL-HDBK-210

DOD Petroleum Procurement Inspection Manual, DSAM 4155.1, AR 715-27, AFM 74-3

Identification Methods for Bulk Petroleum Products Systems, MIL-STD-161

Fuel Storage Tank Cleaning at the Shore Establishment (Finished Products Tanks), NAVDOCKS P-342, Bureau of Yards and Docks, Dec. 1961

Design Manual, Liquid Fueling and Dispensing Facilities, BuDocks DM-22, Bureau of Yards Docks, Nov. 1961

Structural Fire Fighting Manual, OPNAV 11320.15, Office of the Chief of Naval Operations, 1953

Operating Instructions for MSTS Contract-Operated Tankers (USNS) and Bunkering Instructions for Consecutive Voyage Chartered Tankers (TANKOPINS), COMSTS INST P3121.3B, Military Sea Transportation Service.

Operating Instructions for MSTS Time-Chartered Tankers. COMSTS INST P3121.6A

An Appraisal of the Petroleum Industry of the U.S., U.S. Department of Interior, January 1965

Operating Procedures for Bulk Petroleum and Coal Products, DSAM 4220.1, AR 700-9100-5, AFR 67-142, MCO 10340.6

Material Inspection Service U.S.N., Administration Manual, Petroleum Inspection Reports, ONM INST 5000.3, Vol 2, Chap 7, Office of Naval Material

Defense Material Interservicing Manual of Procedures, DSAM 4140.1, AFM 67-11, AR 1-38, MCO P7020.5A

Packaging, Packing, and Marking of Petroleum and Related Products, MIL-STD-290

Federal Test Method—Lubricants, Liquid Fuels, and Related Products, Methods of Testing Standard No. 791

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The above list of publications includes those most frequently used in the operation of Navy fuel facilities, and is not considered to be a complete listing of all government publications relating to petroleum products.

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Standards on Petroleum Products and Lubricants (ASTM Manual); prepared by ASTM Committee D-2 on Petroleum Products and Lubricants (issued annually); published by the American Society for Testing Materials, Philadelphia, Pa.

Motor Oils and Engine Lubrication, Carl W. Georgi; Reinhold Publishing Corporation, 1951

Petroleum Products Handbook, Virgil B. Guthrie; McGraw-Hill Book Co., New York and London, 1960

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Principles of Petroleum Geology, William Low Russel; McGraw-Hill Book Co., Inc, New York and London, 1951

Guide for Tank Venting, American Petroleum Institute Bulletin RP 200

The Filtration and Dehydration of Aviation Fuels, American Petroleum Institute Bulletin 1501

Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, American Petroleum Institute Bulletin RP 2003

Cleaning Mobile Tanks Used for Transportation of Flammable Liquids (Section A - Tank Vehicles), American Petroleum Institute Accident Prevention Manual No. 13.

Cleaning Petroleum Storage Tanks (Section B - Gasoline Tanks), American Petroleum Institute Accident Prevention Manual 1B.

In addition to the foregoing commercial publications, there are many more available on the subject of petroleum from various commercial sources.

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* U.S. GOVERNMENT PRINTING OFFICE: 1970—394-067/S-43

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